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Francis H. Richards

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CASSIER'S MAGAZINE.

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THE FALLS AT MONTMORENCY CANADA.

ELECTRIC POWER FROM THE MONTMORENCY FALLS IN CANADA.

By C. C. Chesney.

THE Falls of Montmorency, situated eight miles below the far-famed and historic city of Quebec, are the scene of one of the most interesting and successful electric transmissions of power in America. The cataract, almost too well known to need any description, is the chief natural attraction in that vicinity, and while not possessing the magnitude of Niagara, there is yet something of the same grandeur and magnificence in the wild rush of its waters, and the same deafening roar that stuns for a moment the mind of the most stolid beholder. From a height of more than 275 feet the waters fall perpendicularly over the face of the rock, forming, in succession, furious cascades and seething pools in the ravine below, and rushing off to meet the waters of the majestic St. Lawrence.

It is the especial object of this article to call the attention of those interested in the general development of water powers, and especially of those who may have occasion to investigate the problem of the transmission and distribution of power by alternate currents of electricity, to the method and apparatus there used, in the belief that it is an object lesson, not only of scientific interest, but of great practical value.

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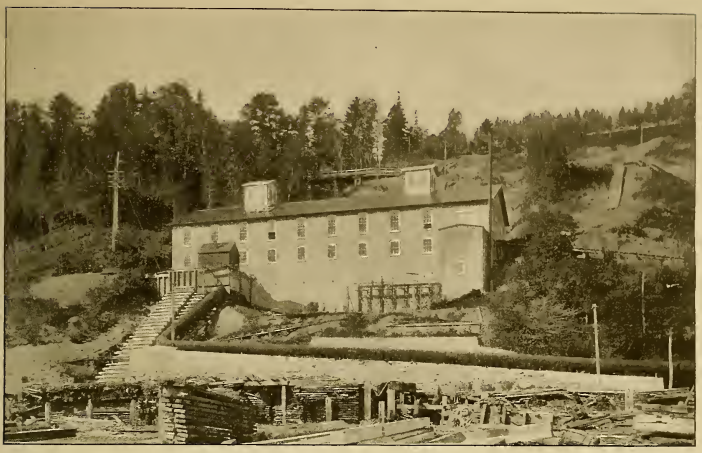
To a people less conservative than the "habitant,"—less apt to revel in the memories of the shrouded past,—the utilitarian possibilities of this beautiful cataract might have appealed earlier, but with this mystic people, and within sight of one of the largest cities above the face of the falls, with the object of utilising some of the power for manufacturing. A cotton mill was built at the foot of the bluffs, and, shortly after, a small arc station was erected for the purpose of doing arc lighting in the city of Quebec.

MONTMORENCY FALLS, SHOWING NOS. 1 AND 2 GATE HOUSES.

of Canada, the massive energy of Montmorency was allowed to waste away for years in dashing itself into the chasm below.

It is but a few years ago that a company, organised in Quebec, constructed a dam across a narrow gorge in the Montmorency river at a point 1500 feet

In the year 1889 the present Montmorency Electric Power Company established, in connection with the arc plant, a small incandescent plant of about 100 horse-power capacity, using 2000-volt alternate current machines, built by the Royal Electric Company of Montreal, and transmitting the current



THE LIGHTING STATION, SHOWING THE 48-INCH STEEL PIPE SUPPLYING THE COTTON COMPANY WITH POWER.

to Quebec with a loss of over 50 per cent. This very unsatisfactory and uneconomical plan was continued until the summer of 1894, when a change of management brought to the service of the company the well-tried experience and engineering ability of Mr. Frank H. Badger, Jr., as general manager, and Mr. Louis Burran, as electrician, to whose intelligent work and attention to the practical details the final success of this plant is largely due.

Acting under the advice and direction of these gentlemen, the company increased the capacity of the old dam to a minimum of about 12,000 horse-power. A short tunnel was run through the solid rock, connecting the dam to the wooden flume which continues along the face of the adamantine bluffs for a distance of 1500 feet to the gate house on the brow of the hill. The construction of this flume was a task of considerable magnitude, involving the exercise of much engineering skill. From the gate house, on the brow of the hill, a steel-riveted tube, having a diameter of 72 inches and a length of 1100 feet, is carried down a steep incline to the power house, where the pipe-line terminates in a large steel receiver which supplies the water to the turbines.

Owing to the extremely high head and the great velocity at which the wheels must necessarily run, they were required to be very simple, stronger and more compact than is the general rule. The wheels adopted are the "Little Giant" turbines, manufactured by J. C. Wilson & Co., of Picton, Ontario. The noticeable feature of these wheels, besides their simplicity, is the almost entire absence of lateral or end thrust, so frequently found in the ordinary types. They have two sets of buckets, keyed on the same shaft, and the buckets are so formed that whatever end thrust there may be from the one set is counteracted by that of the other. The particular size installed at the Montmorency falls has a capacity of 700 horse-power and runs at a speed of 600 revolutions per minute. The "Little Giant" turbine is comparatively little known outside the Dominion of Canada, but some idea of its simple and compact nature can be gained from the fact that this 700 horse-power wheel is only 21 inches in diameter and

THE MAIN STEEL PIPE, WITH GATE HOUSE IN THE DISTANCE.

has an extreme length not exceeding 2 feet.

The generating station is a two-story structure, built of native stone, and is 150 feet long by 50 feet wide. It is situated in a picturesque and convenient spot between the hills and the Quebec, Montmorency & Charlevoix Railroad. The first floor of the building is devoted entirely to the turbines and the necessary gate mechanism. Along one side of the room the numerous wheels are arranged in a row, from which the belts proceed at an angle of 45 degrees to the dynamos on the floor above. The water is taken from the receiver in this same room and is discharged partly into the tail race which empties into the St. Lawrence river, and partly into the 48-inch steel pipe which supplies water to the wheels in the mills of the Montmorency Cotton Manufacturing Company.

The second floor is the dynamo room. It is a large, well ventilated and well lighted space, having practically the same dimensions as the building. To the practised eye of the engineer, it is at once apparent that the design and construction here have been carried out in accordance with the best engineering skill. It is unfortunate that electric lighting stations, as a rule, have been hurriedly constructed with any sort of material that happened to be near at hand, and equipped with that apparatus which was offered at the lowest price, regardless of quality. This room is, therefore, of more than usual interest, since in its equipment, or that proposed for future developments, every necessary improvement has been introduced which in any way promised to increase the reliability and efficiency of the plant, and to reduce the cost of operation.

The problem in electrical engineering which was presented to the Montmorency Electric Power Company is typical of the problems presented to all enterprises for the utilisation of a waterfall by the transmission and distribution by electricity of its energy to distant points. The prime requisites in any such system for power transmission and distribution are, necessarily, simplicity and reliability. The simplicity and reliability of the single-phase alternating system are well known to all electricians and the electrical public in general. This system has been proven and tried

in numerous cases where it has been the sole dependence of the larger enterprises, and where the practicability of transmitting power in bulk by this system has been demonstrated beyond question. It lacks, however, range and flexibility; it lacks a motor which commercially answers the requirements of power distribution; and it lacks the ability to be readily converted into direct currents for railroad and electrolytic work.

In the multiphase systems, however, which have been developed within the last few years by the variouselectrical companies, are to be found all these requirements. Coupled with the simplicity and reliability of the single-phase systems, are to be found range and flexibility. The induction motor forms the missing element for commercial power work, and extends its range far beyond that ever realised by the direct-current motor. When we now add the two-phase or three-phase rotary transformers, we have a system, ideal not only for long distance transmission purposes, but ideal for general central station work, whether the energy be primarily furnished by steam or water power.

Naturally, then, in order to obtain the most complete and commercial results from the power at its disposal, the system adopted by the Montmorency Electric Power Company is a multiphase system. The particular multiphase system is the S. K. C. (Stanley-Kelly-Chesney) two-phase system as applied by the Stanley Electric Manufacturing Company, of Pittsfield, Mass., U. S. A.

The generators are situated on the north side of the dynamo room. The foundations are of solid masonry, through which are run a number of tie rods which hold an insulating cap to the solid bed rock of granite. The insulating cap consists of 10 by 12-inch timbers which have been boiled in paraffine in order to completely remove all moisture. The bed plates of the machines are held in place by lag screws set into the paraffined timber. Each generator delivers alternating currents, differing in phase by 90 degrees, to two independent circuits at an electromotive-force of from 5200 to 5700 volts. By means of rheostats in the fields of the generators, the electromotive-force can be varied between these limits, to meet the requirements of the circuits.

The frequency is 66 periods per second—that is, the current is reversed approximately 8000 times a minute. The generators are what are commonly known as 8000-alternation machines. This frequency was selected as being one of the standard frequencies advocated by the engineers of the Stanley

ALONG THE PIPE LINE.

Electric Manufacturing Company and in preference to 133 periods per second (16,000 alternations); for, while the loss in the core of the transformers was increased from 20 to 30 per cent., and the regulation of the generators from a total of 2 per cent. to a total of 3 per cent., the self-inductive drop in the transmission lines was such an important factor that the lower frequency was considered preferable, as giving, on the whole, a better regulating and more economical system.

The currents delivered by the generators are carried by heavily insulated cables to the switchboard, where the attendant, by suitable switches, may connect the generators to the transmission lines. Two separate pole lines have been constructed to Quebec. One follows the route of the Quebec, Montmorency & Charlevoix Railroad, carrying two transmission lines, each having a capacity of 500 K. W.; the other follows the old Beauport road, carrying one transmission line of a capacity of 500 K.W., and provision for an extra line. All the lines are entirely overhead, and are entirely supported on wooden poles, with the exception that at the crossing of the Charles River they are carried across the river on iron poles, 125 feet high.

Triple petticoat porcelain insulators were used, and were made especially for this plant by a Canadian manufacturer, differing, however, but slightly from the design now in common use for high-voltage work. The line wire is No. 0, B. & S. bare copper. The drop, due to the ohmic resistance of the wire, is 8 per cent., which is increased by the self-induction to 10 per cent. On the extreme ends of the top cross-arms of each pole line are strung galvanised iron wires, which are grounded at every third or fourth pole.

These iron wires, together with lightning arresters, placed at each end of the transmission lines, give a complete and safe protection from all lightning storms. So perfect has been this protection, that a discharge in either the generating station or sub-station is practically unknown.

The transmission lines enter the city of Quebec in that portion known as St. Rochs, and the sub-station is located in the centre of the industrial district, where power is needed for the

THE DYNAMO ROOM.

ANOTHER VIEW OF THE DYNAMO ROOM, SHOWING PARTICULARLY THE 600 K. W. "S. K. C." GENERATORS.

tanneries and shoe factories for which the city is noted. The sub-station is 90 feet long by 65 feet wide, and is two stories high, built of brick, with a stone front. The building consists of a store-room on the second floor, the offices of the company in the front, on the first floor, with the room containing the distributing switchboard immediately in the rear. The transformer house is a part of the same building, but only one story high.

The transmission lines enter the sub-station through the cupola to the high-potential receiving switchboard, which contains special high-voltage switches. These switches are mounted on marble and are fitted with special self-enclosing boxes, which are intended to cut off any possible arc that may be formed on opening the 5000-volt circuits.

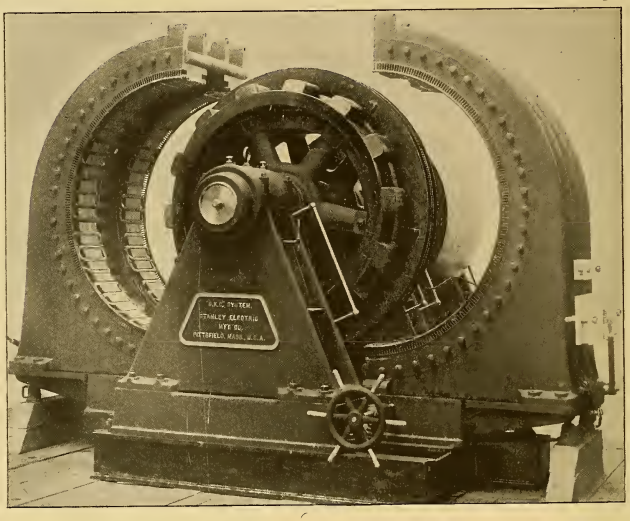
From the transmission lines the current of the generators is carried to the step-down transformers, where the electromotive-force of transmission is transformed into the distributing electromotive-force of 2000 volts. These transformers are the regular indoor type of the Stanley Company, and are arranged on a rack, in two tiers, five wide and two deep, in such a manner that the air has free circulation, or that they may be artificially ventilated if it be so desired. They are of 50 K.W. capacity, and are connected in pairs. Each is wound for a primary electromotive-force of 2500 volts and a secondary one of 1000 volts. The primaries of each pair are connected in series for receiving 5000 volts, and the secondaries in series for delivering 2000 volts to the distributing system. This arrangement gives an additional safeguard by lessening the voltage on any particular coil, and in case of a burnout in any one transformer, the other will carry the load for a time until the relay transformer can be cut in. The insulation of each transformer was tested with 10,000 volts. The regulation of each transformer from no load to full load is about 1 per cent. The average efficiencies of the entire transformer equipment, as shown by the shop tests, are :—

Efficiency,	full load,	97.8 per cent.
"	half load,	97.9 per cent.
"	quarter load,	97 per cent.

The transformers are divided into two sets of eight transformers each, with a relay of two transformers which can be cut in or out without stopping

the service. Three secondary distributing circuits are carried to the distributing board in the next room. Provision has been made, however, for two more circuits of the same capacity.

coils. The weight of this portion of the machine is 42,580 pounds. The field or exciting coil is circular, 94 inches in diameter, and wound on two copper bobbins, each 4¼ inches wide.



A 600 KILOWATT "S. K. C." TWO-PHASE GENERATOR DRAWN APART.

The current from the secondaries of the two sets of transformers is carried to the bus bars of the distributing switchboard, from which it is furnished to the numerous city circuits for light and power.

The generators are the S. K. C. inductor type of two-phase machines, running at 286 revolutions per minute. Each generator has a capacity, at 5700 effective volts, of 100 ampères. They are the largest inductor machines that have ever been built, and are the first and only practical machines that have ever been constructed for such a high initial electromotive-force.

The armature is stationary, consisting of two sets of laminated iron rings, connected by steel rods four inches in diameter. On the inner surface of each laminated armature ring are fifty-six grooves for receiving the armature with a copper strip four inches wide and .026 inch thick. It is insulated between the layers with a special oil-cloth which is practically indestructible at temperatures under 150° C.

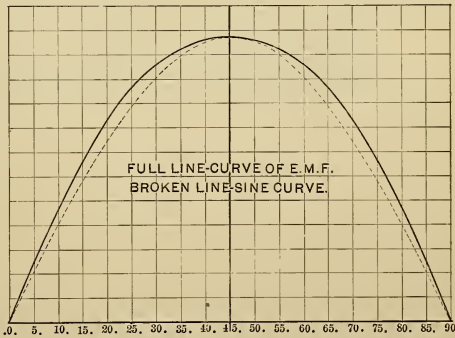
To the dynamo builder the advantage of constructing a field coil on such lines is very apparent. With a free circulation of air, and every turn of the winding being, for cooling purposes, practically in contact with the moving air, there is no possibility of overheating in any portion of the coil. The copper bobbin, absorbing all discharges, prevents any excessive rise of electromotive-force on the coil, which might be caused by carelessly, or, under extreme circumstances, intentionally, opening the field circuit under full charge.

There are, in all, 56 armature coils, 28 for each phase. The coils are small and were wound in a lathe. Each coil

was carefully insulated to stand 15,000 volts before placing it in the armature. The insulation of the completed armature was tested, finally, with 12,000 volts.

The inductor, the only moving portion of the machine, is a steel casting, 43 inches long and 84 inches in diameter, upon the periphery of which are two sets of polar projections of iron laminæ, fourteen at each end. The weight of the inductor, including the shaft, is 28,470 pounds. The net weight of the completed machine is, approximately, 100,000 pounds.

In the operation of alternating current motors, and also of transformers, it is now generally recognised as important that the currents and magnetic fluxes should vary sinusoidally, for the more nearly such a condition is approached, the less are the losses and idle currents. A first step toward obtaining these conditions is the making of the impressed electromotive-force of the generator sinusoidal. The flux between a field pole and the opposite iron of the armature distributes itself, so that it is, at every point, inversely proportional to the reluctance of the gap at that point, or inversely proportional to the distance from the field pole to the armature iron; that is, the electromotive-force at any instant is inversely as the clearance. In order, then, to obtain an electromotive-force following the sine law, the pole faces of the inductors of these generators, as well as the pole faces of the inductors of all generators manufactured by the Stanley Electric Manufacturing Company, are so shaped that their curvature may be expressed by a formula which was derived by Mr. Kelly, of the Stanley Company, and is contained in a United States patent issued to him.



E. M. F. CURVE OF THE GENERATORS AT MONTMORENCY.

In the design of the inductor machine it has been found by the writer that any deviation from this law, or the use of any other than a sinusoidal electromotive-force has resulted in increased losses in transformers and unsatisfactory running of motors. In one instance the output of a 20 horse-power motor was reduced 25 per cent. on a machine with a distorted wave, and the condensers, which were intended to balance the lagging currents of the motor, were absolutely useless for that purpose.

A novel feature has been introduced for the first time in these generators. The entire distributing system has been arranged to be run in parallel, and, in order to do this, the generators must be kept in phase. There are some objections, however to paralleling 5000-volt machines through their principal circuits—also do difficulties occur in paralleling long transmission lines. A defect arising in any wire of one line, such as a ground or leak, affects all the wires in all the lines, so that if at any other point another ground occurs, the generators between the two grounded points are all short-circuited. To overcome this difficulty, the mains from the different machines are kept separate and the secondaries of the step-down transformers are connected in parallel with the supply mains.

In consequence, unless the line from one generator has two weak points, there is no leakage, and, at any rate, the leakage due to two weak points can affect directly only one generator. In order to keep the generators in

phase under these conditions, a separate and distinct synchronising winding gives an electromotive-force of 120 volts and has a synchronising capacity of about 100 K.W. This, together with the effect that can be obtained through the paralleled secondaries of the step-down transformers is sufficient to give perfect parallel running. The load can be readily shifted from one generator to the other by varying the quantity of water supplied to the turbines.

The exciters are two slow-speed, direct-current machines of 12 K.W. capacity, each of sufficient capacity to excite the fields of the three alternators.

Some of the electrical data of these machines are interesting, as showing the improvement in dynamo design and the possibilities of the inductor type of machine. From the shop tests we have the following :—

Maximum loss in field,	4000	watts.
Loss in armature iron, friction and windage	20,000	"
" armature copper	7000	"

From these we calculate the efficiencies :—

Full load,	95.1 per cent.
Half load,	92.3 per cent.
Quarter load,	87 per cent.

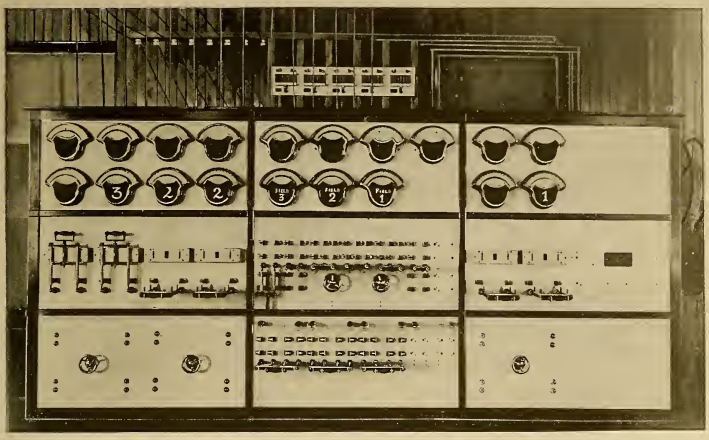
The rise of temperature after a run of twenty-four hours, with full load, is as follows :—

Field coil,	12° C.
Armature iron,	21° C.
Inductor iron,	7° C.
Armature coils,	26° C.
Bearings,	21° C.

REAR VIEW OF THE DISTRIBUTING STATION.

The regulation, that is, the variation of the electromotive-force from no load to full load, with same speed and same field excitation, was 3½ per cent. With full load on one phase and no load on the other, the percentage difference of electromotive-force was 3½ per cent.

The design of the switchboards and the general features of their construction can be best understood by reference to the illustrations on pages 13 and 14. Both the generator and distributing switchboards are built of marble, supported upon wooden frames,



THE GENERATOR SWITCHBOARD.

and the panel method of construction is followed throughout. Each slab of marble was tested for metallic streaks, with a pressure of 12,000 volts.

The generator board consists of three sections, of three panels each. The lower panel of the left-hand section carries the two rheostats for controlling the fields of two of the generators. They are mounted on the back of the board, and only the handles and the heads of the supporting bolts show. The middle panel carries four machine switches with self-enclosing arc cut-offs, two for each generator, and one of these for each phase. These connect directly to two of the four-wire transmission lines.

It is never intended to open these switches under load, except in the case of great emergency, when the automatic cut-offs will take care of any discharge from the line, or any tendency to arc. When a generator is to be taken out of work, the load, if it is running in parallel with another, is shifted to the other by gradually cutting off the supply of water to its turbine; after that, the switch can be opened without difficulty. If the generators are running independently, the load is first transferred at the sub-station before opening the switch.

The upper panel contains four ammeters, two for each transmission line, and four voltmeters, with high-potential station voltmeter transformers placed directly at the back. The right-hand section is exactly the same as the left, with the exception that it is, at present, equipped for only one generator and transmission circuit.

The lower panel of the middle section carries three four-pole, single-throw switches for connecting the synchronising winding of the generators in parallel. The synchronising lamps are shown just above.

The middle panel is the exciter panel, carrying the necessary switches for paralleling the two exciters, and for charging the field of any generator from any exciter if the exciters are running independently.

The upper panel contains three direct-current ammeters for the fields of the generators, and also four alternating current voltmeters, with voltmeter transformer at the back, connecting to the 2000-volt potential lines which return from the sub-station.

The distributing board was originally

THE DISTRIBUTING SWITCHBOARD.

designed for parallel running only, but it was afterwards learned that on rare occasions ice accumulates in the turbine feed pipes, which affects the speed of the wheels and makes parallel running an impossibility. In consequence, the original design was changed to permit either independent or parallel running of the generators.

The two sections on the left of the board are organised for lighting alone, and to permit the transfer of any two-wire circuit upon any of the possible four sets of step-down transformers. This is accomplished by a series of three double-throw, double-pole switches. At the extreme top of this section are the automatic circuit-breakers. The two sections on the right of the board are organised for light and power, and differ from those on the left only in that the four-pole double-throw switches are substituted for the two-pole double-throw.

The two centre sections are the same in design. The upper panels contain the voltmeters and ammeters for the various circuits. The middle panels carry four-pole double-throw switches, and are connected to the secondaries of the step-down transformers in such a manner that, if the switches are thrown up, three sets of two-phase secondaries are connected to three separate sets of bus bars; if they are thrown down, all the secondaries of each phase are connected in parallel. The lower panel carries the ground detectors of the ordinary transforming type. The whole switchboard is 26 feet long and 11 feet high.

All the motors now in use by the Montmorency Electric Power Company are the S. K. C. induction motors. These motors were described by Dr. Bell in the January number of this magazine. They vary in size from one horse-power to 30 horse-power, and do all kinds of work, running the tools of carpenter and machine shops, driving the saws and wood-planers of planing mills and handling the freight elevators in various mills and in wholesale warehouses with perfect satisfaction. It is now well understood that the magnetising current of an induction motor lags behind the applied electromotive-force, and that a lagging current in practise involves considerable loss and expense, by necessitating the use of larger conductors and generating apparatus, while it seriously interferes with the proper regulation of the generators and increases the normal drop of the line.

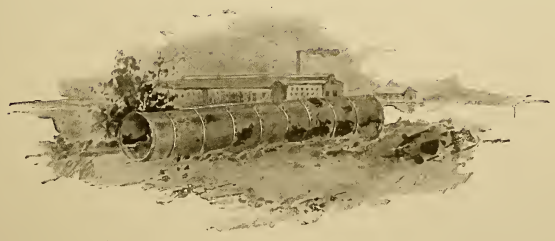
In the S. K. C. motor the magnetising current is furnished by condensers; the motor then takes current in pro-

portion to the load. Two condensers are connected in multiple with the fields of the motor, and each has a capacity in ampères at the working voltage practically equal to the no-load current of each field of the motor. If there is no distortion of the current wave, the apparent energy taken by an induction motor with condensers is equal to the real energy.

An interesting example of the value of condensers on induction motors is shown in a small plant in New England. The generator was a 60-ampère two-phase machine, manufactured by one of the larger electrical companies, and was furnishing power to a number of small induction motors. The motors were doing all kinds of general factory work and running ten hours a day. The average load on the motors was about one-quarter of their maximum. The amount of current furnished by the generator to the motors was 52 ampères at 1152 volts. The power factor was 0.505.

When the motors were supplied with condensers, the current was reduced to 28 ampères at 1150 volts, and the power factor was increased to 0.863. The reason that the power factor was not increased to unity was the existence of harmonics in the curve of the electromotive-force of the particular machine in use.

As to the commercial efficiency obtained in this plant, it is interesting to note that, with the generator working at full load, for every 100 K.W. of energy delivered to the pulley of the generator, 95.1 K.W. are delivered to the line at the generating station; 87½ K.W. are delivered to the terminal of the step-down transformers, and 86 K.W. are delivered to the distributing mains of the sub-station.



COOLING SYSTEMS FOR CONDENSING WATER.

By W. G. Starkweather.

THE use of a partial vacuum in the operation of a steam engine is an apparent case of "getting something for nothing." As atmospheric steam has available pressure if condensed, it only remains to supply the condensing medium in requisite quantity, and a means for removing the products of condensation to gain several advantages over a plant operated non-condensing. The increase of pressure in the engine cylinder which results from condensing varies in well designed plants from 12 to 14 pounds, and extends nearly the entire length of the stroke, so that a gain in pressure here, as of back-pressure when non-condensing, is of much more effect than an equal increase in boiler pressure, and is also attained without additional fuel consumption. It is practically that much added to the mean effective pressure.

If the work on an engine remain constant and the terminal pressure be not abnormal, the addition of condensing apparatus generally results in higher economy, which is measured approximately by the shortening of the cut-off, although an earlier cut-off may cause greater initial cylinder condensation. Distinction should be made, however, between increase of economy and increase of power, as the two, in the case under consideration, are by no means synonymous. The engine gains the pressure due to the vacuum, but the additional work of the air and circulating pumps must be performed, and this amount must be deducted from the total gain in power in the engine cylinder to determine the net gain. The ratio which this work bears to the total of the engine is seldom less than 1, or more than 5 per cent.

In case, also, this pumping is not done by the main engine, or, at a corresponding economy, by other smaller engines, the difference in economies detracts from the total economy as gained by the vacuum, and, in any case, requires a proportionate amount of steam. Then, again, the feed water, which, in non-condensing plants, may be at 212 degrees when it enters the boiler, cannot, in condensing plants with rod or belt-driven air pumps, be much higher than the temperature of the hot well, or about 120 degrees. When independent air and circulating pumps are adopted, and their exhaust steam is utilised, it may rise to 140 degrees, or even higher.

There thus results, for single-cylinder engines under normal conditions, a net gain in power, by the addition of a condensing system, of from 20 to 25 per cent, or in economy of steam, of from 15 to 20 per cent. over the same engine non-condensing. Engineering opinion is unanimous, that in almost every location distant from the centres of fuel supply, it pays to condense.

In some parts of the United States as well as in Europe where steam coal prices are very high and where, at the same time, water for condensing is not readily obtainable, engineers have developed extreme measures to gain the advantages of vacuum, using special cooling systems for the use of condensing water over and over again. The methods there adopted are applicable, with some modifications, due to different climatic conditions, to any locality away from natural cooling water, and an account of them here may, therefore, prove interesting The use of these systems with proper attendance has a particular advantage, also, and one which is not

attained with ordinary jet condensers where the overflow is wasted, in that they permit practically pure feed water to the boiler.

In brief, the method is to freely expose large surfaces of the water from the condensers to the atmosphere, thus cooling it sufficiently to be used over and over again, new water being added to compensate for evaporation and seepage. This exposure of the water is accomplished by (1) pools, (2) trays and pans, and (3) spray.

THE POOL SYSTEM OF COOLING CONDENSING WATER.

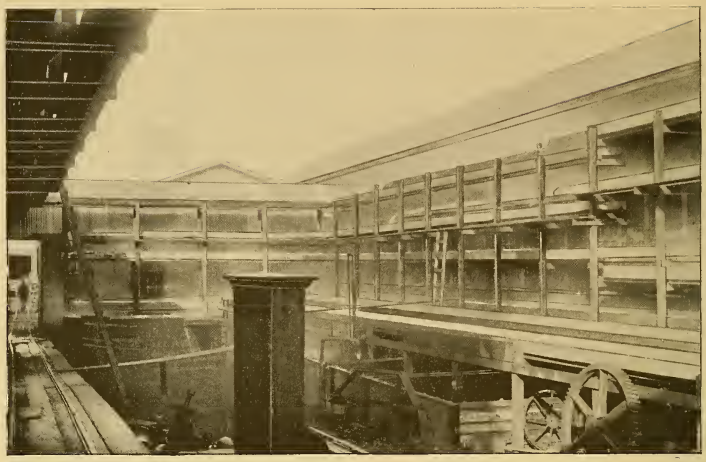
The water, being at the temperature of the overflow, parts with its heat to the surrounding air in several ways :—

(1) Evaporation, which is the most important and by which heat passes from the water to form vapour. It has become apparent from experience with coolers of every description, that water can pass away by evaporation at atmospheric temperatures without further cooling of the water, and that such loss of water is a waste. In fact, it is a question, in locations where water is expensive, whether evaporation should not be stopped at a temperature somewhat higher than the atmosphere, as the few degrees of cooling at the lower range are obtained at the expense of much more water than an equal number of degrees near the highest temperature.

(2) Transfer of heat also takes place by convection with the cooler air and surfaces. In the pan system, described further on, the proportion thus delivered is larger than in the spray system, in which the loss is probably greatest by evaporation.

(3) A transfer of heat to surrounding bodies also ensues through radiation, and this is supposed to be about equal in quantity to that due to convection ; but it is probably less. Both the latter means of cooling involve little or no loss of water, which is a desirable feature where water, as is usually the case, costs money.

The pool system is illustrated in the cut above. It provides for a series of artificial shallow basins, generally lined with cement to prevent leakage.



THE PAN SYSTEM.

The water from the condenser is discharged into one end, and is drawn from the other. Division walls compel a long travel from inlet to outlet, thus ensuring time for evaporation and the presentation of new masses of water to the cooling action of the atmosphere. This system requires large ground area, fouls very easily, may leak to a large extent, unnoticed, and is the least efficient in cooling for the first expenditure.

The pan system, illustrated above, makes use of a series of galvanised iron or wooden pans, or water-ways, arranged in continuous tiers, and with enough fall to run or drain the water in thin sheets from ¼ to ½ inch deep and from 24 to 48 inches wide, back and forth, in contact with the air. On top, evaporation is most efficient, but the underside of the pan cools by the other means mentioned above. This method has the comparative disadvantages of requiring great space, and entailing considerable weight, while it is of large first cost, both in material and labour. Moreover, it easily becomes fouled and leaky.

The spray system, which is now coming into use, is far simpler, cheaper, and more compact, and does not foul so quickly as the other two. In it the water either gravitates, or is forced, as shown in Figs. 1 and 2, through a perforated metal sprayer which divides it into fine streams. It attains the desideratum of large surface by a much smaller first outlay than any other system, and the avoidance, in large measure, of their disadvantages. Graduated and removable screens are placed in some convenient channel where the dust and oil are entirely removed from the water.

The system shown in Fig. 2 is the result of experience with all the other forms, and represents the latest development in "coolers." It has several good points not found in other systems. If too strong a wind is blowing, and spray is consequently being driven from the collecting basin, the circulating pump can be slowed down and the height of the spray thus decreased. Again, if evaporation is too slow and the injection not cool enough to produce a good vacuum, the speed of the pump can be increased, the spray raised higher, and the amount of surface thus augmented.

Regarding the effect of various atmospheric conditions on the amount of

water lost by evaporation, opinions of users of the coolers agree that the loss remains practically constant throughout the year. As to the absolute amount of loss, there is a scarcity of information, but it is the general opinion that the loss is usually very small, possibly one or two per cent. of the total amount circulating. The ratio which this loss bears to the feed water is important, as it determines the degree of purity of the water.

In all the systems which are described more in detail below, the condensing water returns to the condenser at about 90 degrees temperature, having lost in the neighborhood of 40 degrees in the cooler. The loss in temperature is affected by the character of the atmosphere, a cool dry day with brisk wind being generally considered the most favourable for cooling, as the combined transfer of heat, due to convection, radiation, and evaporation, then reaches a maximum.

There are various combinations of the coolers with the condensing apparatus, the arrangement of each depending largely on the locality. In case the cooling system is placed on a roof, or

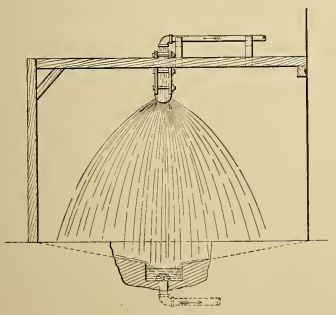


FIG. 1.

where it is necessary to elevate the overflow water, the question of pumping becomes of considerable importance. The air pump, when jet condensers are used, will raise the overflow, if it is proportioned for such additional duty, and in several instances as noted below, is performing the extra circulating duty against heads of as much as 22 feet. There comes a point, however, when the air pump can not be expected to do this work, and a separate circulating pump is then added. When the cooler is on the roof of a high building, and raising the water to it would amount to a proportionately large part of the total power, a surface

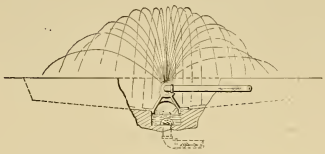


FIG. 2.

condenser can be used with a closed or U-system of piping and a circulating pump as in Fig. 3 on the next page. As the water is in equilibrium in the U, the necessity of forcing it higher than required for the cooler alone is obviated and the cooler can thus be placed at any height above the condenser.

Coming to the specific cases of cooling apparatus in use in California, there is, first, the pool system, of which the Sperry Mill, at Hollister, furnishes a fair example. The engine is a 16x36-inch Wheelock, indicating 140 H.P. It discharges its exhaust into a 6-inch siphon condenser which maintains from 18 to 20 inches of vacuum. The discharge from the hot well, or base of the condenser, gravitates to a wooden box from which it falls a few inches into the pool, at a temperature of 150 degrees. It then flows very slowly from the receiving pool through the other pools, and reaches the suction of the injection pump at 115 degrees temperature. These pools aggregate 10,000 square feet, are from 12 to 18 inches deep, and are lined with cement. Notwithstanding all precautions, the leakage is very large, and new water must be constantly added. There are 71 square feet for each indicated horse-power.

Another example of the pool system is at the Oakland Cotton Mill. The engine there is a 30x48-inch Corliss,

making 64 revolutions, and develops 500 I.H.P. It drives from its crosshead a 26x10-inch air pump which serves a 24x48-inch jet condenser. The overflow is 8 inches in diameter, and the water is lifted 4½ ft. by the air pump to the cooler, which consists of three pools, one measuring 50x50 ft., and the other two 50x75 ft. They are 7 ft. deep, with 400 ft. of 36-inch raised waterway around the edges and through which the water first flows. Twenty-five thousand gallons of new water are

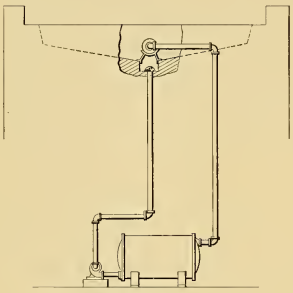


FIG. 3.

added every 24 hours, and the overflow discharge amounts to 13,000 gallons per hour. The overflow temperature ranges from 130 to 140 degrees, and the injection is rarely above 80 degrees or 90 degrees. The total surface amounts to 11,200 square feet, or 22½ square feet per I.H.P.

It is the second class of coolers,—the pan system,—which is found in greatest number in San Francisco. The Howard Street Cable Railway has a cooler of this kind on the roof of its power house. The engine is a cross-compound O'Neil poppet valve engine 29x44x60 inches, running 50 revolutions, and averaging 550 I.H.P. From the crosshead a 20x24-inch double air pump is driven with a jet condenser. A compound circulating pump raises the overflow water from the hot well 90 feet to the roof, on which is placed the cooler. There are five tiers of pans, one above the other, 7 feet wide, made of No. 14 galvanised iron. The entire cooler is 112 ft. long and 20 ft. wide and the water flows a distance of about 600 ft., presenting a surface of 8260 square feet for cooling, or 15 sq. ft. per I.H.P., the water being ½-inch deep. As the pans are about 8 inches apart vertically, there is ample opportunity for air to circulate between them. A vacuum of from 22 to 25 inches is obtained, depending on the temperature of the atmosphere and its humidity.

At the power house of the Union Street Cable Railway the engine is a cross-compound Corliss, 18x24x36 inches, making 76 revolutions, and averaging 100 I.H.P. The air pump for the jet condenser is 12x18 inches and is driven by an eccentric on the main shaft. A circulating pump with water end 10 inches in diameter and 12-inch stroke, raises the overflow water 40 ft. to the roof. The cooler is similar to the one described above, and is 110 ft. long by 14 ft. wide, with three tiers of pans, 60 inches wide, aggregating, with a storage tank, 3550 sq. ft., or 35½ sq. ft. per I.H.P. A vacuum of from 22 to 26 inches is obtained. The water requires from 20 to 25 minutes to make the complete circuit and loses 1700 pounds per hour by evaporation, the temperature being lowered about 40 degrees.

The California Street Cable Railway has a triple expansion O'Neil poppet valve engine 14x20x30x54 inches, running 64 revolutions and developing 350 average I.H.P. The air pump maintains a vacuum of 23½ inches, and a circulating pump forces the water 70 ft. to the roof. The cooler is one of the largest in San Francisco, having 8050 sq. ft., mostly arranged in tiers of 60-inch pans, the total length of the water way of this width being 1400 feet. There is thus obtained about 23 sq. ft. per I.H.P. The total overflow discharge is 35,000 gallons per hour, and the loss by evaporation amounts to about 8000 gallons in 20 hours. At one time this plant was operated non-condensing and required nearly as much city water as when condensing.

There are two flour mills in San Francisco which have pan systems.

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The Yosemite Mill has a Thompson tandem compound 14x22x42-inch engine, making 71 revolutions and developing 160 I.H.P. The air pump raises the overflow 23 ft. to the cooler, through a 7½-inch pipe. The overflow amounts to 7800 gallons per hour by weir measurement. The cooler is somewhat straggling and is too small for its work. The aggregate surface is 2100 sq. ft.. The pans are made of wood, 20 inches wide, and carry the water 1½-inch deep. The overflow is ordinarily at 150 degrees, and the injection at 100 degrees, but cold water is added from a well to produce this low temperature. The fall of temperature due to the cooler is 37 degrees. The water is exposed 13 minutes, and falls into four storage tanks with a total capacity of 27,000 gallons.

The Del Monte Mill has a tandem Corliss engine, 16x28x42 inches, running 82 revolutions and indicating on an average, 220 horse-power. The air-pump raises the overflow 8 ft. to the cooler. This consists of a pan system at the edge of, and above, a pool, rectangular in shape, measuring 60x95 ft. The pans are of wood, 11 inches wide, and, with the pool, afford a total cooling surface of 11,552 square feet, which is large enough for twice the power it serves.

The above notes indicate general practice with the pan system in San Francisco. The spray system has two or three examples, the oldest of which is that used by the San Francisco and San Mateo R. R. The engine in that case is triple expansion Corliss of about 400 I.H.P. with independent air and circulating pumps, the latter being of the centrifugal type. The water is delivered from the overflow to the cooler against a head of about 15 ft. It enters the cooler through two vertical pipes at the focus of the eclipse (which is the shape of the collecting basin) and is sprayed by a small horizontal plate, which is fixed over the outlet. The water falls to a wooden platform which breaks it up before its final drop into the collecting pool below. This basin is of concrete and is 50 ft. long by 20 ft. wide. It cools the water about 40 degrees.

Another spray cooler is at Niehaus Bros.' Planing Mill, at W. Berkeley. The engine is a vertical Corliss beam, 14x48 inches, making 60 revolutions and developing an average power of 80 horse-power. A 12x18-inch air pump is driven by a rod from the walking beam. The overflow is raised by the air pump 18 ft. to a filtering chamber and is then conducted to a zinc sprayer trough, 14 ft. long, and pierced with fine holes through which the water falls a distance of 12 ft. to collecting surfaces below. It then gravitates to the condenser. In the trough its temperature is 125 degrees. In the basin below it is 84 degrees. The system is compact and efficient, and is successful where three other systems have been discarded.

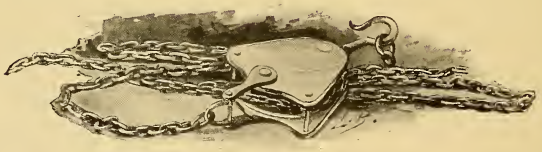
Considering the systems described above, there does not appear to be any law relative to the amount of cooling surface per horse-power. This is caused, perhaps, by the fact that in some of the cases cited, cold water is added from wells, more than enough to compensate for evaporation and seepage, and part of the overflow is wasted. Doubtless, too, the loads which the various engines are carrying has much to do with the disproportion of the data, as a given engine might be developing a certain power larger than normal, and owing to a high terminal pressure, require a very large cooling surface to carry the vacuum. Taking the cases apparently nearest ordinary conditions, it would seem that in the pool system 30 square feet were ample for each indicated horse-power of the engine, and in the pan system 20 square feet would suffice. In the spray system one-tenth of a lineal foot is generally used to determine the length of the sprayer.

It should be borne in mind that these figures are approximate, and are suited only to the climate of San Francisco. This fact is shown very forcibly in the Hollister Mill which is 100 miles south of San Francisco, and

in a rather moist climate. The rating in this case is far above the figure stated, and even then difficulty is experienced in obtaining sufficiently cool water during long runs.

Consideration of the subject makes it apparent that the adoption of any of these systems in cooler climates could easily be effected by slight modification. Where shops or factories are heated by exhaust steam, the cooling or condensing system could, perhaps, be used only in the summer time, or in conjunction with the exhaust heating in winter in case the heating did not require all the steam exhausted from the engine.

The influence of freezing temperature might be embarrassing to cooling systems on roofs and elsewhere, but this danger could be avoided by draining the entire water from the coolers into a large tank in the basement or elsewhere every night. There would be little cause for fearing the freezing of a large body of this size. Ordinarily, cold weather would materially assist the lowering of temperature and the rain and snow added to the system would undoubtedly decrease the water bill where the new water is purchased. On the other hand, the hottest summer day need not be feared so far as vacuum is concerned, as evaporation, and consequently cooling, then reaches its maximum.



POWER DISTRIBUTION IN THE CYLINDERS OF COMPOUND AND TRIPLE EXPANSION ENGINES.

By William M. Henderson, M. E.

THE following remarks upon the distribution of the power in the cylinders of compound and triple expansion engines are based upon the theory advanced by B. F. Isherwood, U. S. N., in his report upon the compound engines of the steam yacht *Siesta*, March, 1883. Figs. 1 and 2 show the two cylinders of a tandem compound engine, illustrating the theory. Briefly stated, the prevailing belief in back pressure reacting from the low to the high-pressure cylinder is shown to be an error. The actual operation appears to be as follows : —

The steam, after impelling the piston of the high-pressure cylinder to the end of the stroke, passes to the low-pressure cylinder and presses equally upon both pistons ; the low-pressure piston is driven onward by the excess of area possessed, after deducting from the central portion the area of the high pressure piston. The marginal ring represents the effective area of the low pressure cylinder, the central portion being non-effective, as to power, but neutralising the area of the small piston, relieving it of all back pressure from that source. There is a back pressure, but it is that acting against the piston of the low-pressure cylinder.

No change of relative position of the two cylinders, such as placing them side by side, or putting a receiver between them, will disturb the mode of action described, excepting needful back pressure due to compression, for, so long as the steam has a passage from the high to the low-pressure cylinder, working on the compound principle, the open communication will outline the area of the small cylinder upon the large, producing the effect described.

This may be further explained as follows :—If we take a pair of scales and place a one-pound weight in each pan, the scales are just as much in balance as when they were unloaded, and are free to oscillate up and down with any disturbing influence. By conceiving two cylinders of equal size, with a piston in each, and steam of any varying pressure, common to both, the effect is the same as in the case of the scale balance ; the pressures on the pistons neutralise each other. If one moves in

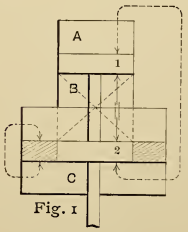


Fig. 1

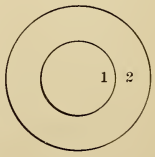


Fig. 2

a downward direction, there cannot be said to be any back pressure on the other, moving upwards.

If we enlarge one of the cylinders, and the piston within it, to, say, double the area, the same balancing effect will be produced to the extent of the smaller piston, which may be imagined to outline its prescribed area upon the cen-

tral portion of the larger piston, leaving a marginal ring equal to the excess area. It is upon this ring portion only that the effective pressure can be exerted. The central portion of the larger piston, corresponding to the area of the smaller piston, neutralizes the area of the small piston, relieving it of all back pressure. From this it would appear that counting as effective the full area of the low-pressure cylinder, and deducting the mean pressure between the two pistons from the steam pressure on the working side of the high-pressure cylinder, is an error, the fact being that the pressure on the working side of the smaller piston is the full pressure there, and the effective area of the larger piston is reduced to the marginal ring before described. This makes the power of the smaller cylinder exactly as much greater as the power of the larger cylinder is made less, being the area of the small piston multiplied by the mean pressure on the large one. The aggregate power is just the same as given by the indicator, but the distribution of the load between the two cylinders is all out of balance.

To obtain a true indicator diagram from the high-pressure cylinder the indicator should be placed in communication with the steam side of the high-pressure piston, and with the exhaust side of the low pressure piston. The indicator cards as now taken, showing a back pressure on the high equal to the mean pressure of the low, are evidently all wrong. In the indicator diagram from the low-pressure cylinder, taken in the usual way, the steam and back pressure are just what are recorded, but the area of the high-pressure piston should be taken from the actual to give the effective area; and if from simultaneous cards taken from both cylinders, the back pressure line traced by the indicator upon the low pressure card is transferred to the high, we will have a proper card representing the working of the high-pressure cylinder, the ordinates counting from this added back-pressure line, and not from the back-pressure line traced by the indicator upon the high-pressure card.

The rules generally advanced for proportioning the cylinders of compound and triple expansion engines are based upon the supposition that there is a back-pressure reacting against the preceding, equal to the mean pressure upon the succeeding piston, which does not appear to be the case. Indicator cards, taken from such engines, show this back-pressure, and engineers are content to accept the evidence; and when the load upon the several pistons is distributed equally by such showing of the cards, nothing further appears to be wanted, and thus the engines are allowed to work with an overbalancing load upon the high-pressure cylinder. In other words, the larger pistons are credited with power to which they are not entitled and the high-pressure piston is performing an excess of work equal to the overcharge. Where a crank shaft is used, the inequality of power of the cylinders is not noticeable, being absorbed by the straining of the shaft. The designing of a cross-compound, direct-acting, pumping engine, without a shaft, brought the matter forcibly to the writer's attention, being a case where absolute equality of power of the two cylinders was imperatively demanded.

Compound Engines.

The area of the low-pressure cylinder of a compound engine is generally accepted as the same as that of a single cylinder engine doing the same work, using the same quantity of steam, with the same initial and final volumes. If there were no fall of pressure between the cylinders, and if there were no loss by non-effective cylinder space, the work would be fairly divided between the two pistons, when one-half of the whole expansion is effected in each cylinder, *i. e.*, making the expansion equal to the square root of the total ratio of expansion. For example, with 16 expansions, the area of the large cylinder being found as for a simple engine, the ratio of expansion in each cylinder would be, according to Rankine, $\sqrt{16} = 4$, and the area of the small cylinder would be one-fourth of the

large, or half its diameter. With steam of 160 lbs. absolute pressure, expanding down to 10 lbs. and falling to, say, 5 lbs. after exhaust opens, piston speed 600 feet per minute, and taking for our standard throughout the following calculations the requirement of 900 horse-power, we have the following:—

RULE 1.

$$\frac{\text{Total horse-power} \times 33{,}000}{\text{M. E. P.} \times \text{piston speed in feet per minute.}}$$

The calculation for a single cylinder engine would be:—$900 \times 33{,}000 = 29{,}700{,}000$ foot pounds; 10)160(= 16 expansions. The mean effective pressure is found by the well-known rule of multiplying the hyperbolic logarithm + 1 of the number representing the ratio of expansion by the absolute pressure at cut-off and dividing the product by the ratio of expansion.

Therefore we have, hyperbolic logarithm of $16 + 1 = 3.77 \times 10 = 37.7$. From this we get, subtracting the 5 lbs. back-pressure, 32.7 lbs. as the mean effective pressure. Then $32.7 \times 600.0 =$ 19,620)29,700,000(= 1514 square inches area of cylinder, which should also be the size of the low-pressure cylinder of a compound or triple expansion engine.

$$\text{Then } \frac{1514 \times 32\ 7 \times 600}{33{,}000} = 900 \text{ H. P.,}$$

friction of engine included.

To determine the size of the high-pressure cylinder of a compound engine of the same power, according to Rankine, we would proceed thus:—4)1514(= 378.5 square inches, and 4)160(= 40 lbs final pressure in the first cylinder, and 4)40(= 10 lbs. final pressure in the second cylinder.

It is manifest that $378.5 \times 40 = 15{,}140$; and $1514 \times 10 = 15{,}140$.

Again, the ratio of expansion in each cylinder we find to be 4, the hyperbolic logarithm of which $+ 1 = 2.386 \times 40 = 95.44 \times 378.5 = 36{,}124$;

And $2.386 \times 10 = 23.86 \times 1514 = 36{,}124$.

So far, these results are admirable, the only drawback being that the engine itself does not appear to work that way, first, because the full area of the low-pressure piston is *not* all effective, the area of the high-pressure piston having to be taken from it; and second, because the uniform back pressure of 5 lbs. has to be allowed in both cases. But the mean area of the differential cylinders is not the same as that of the single cylinder. The effect of 5 lbs. pressure deducted from 378.5 inches of area is *not* the equal of 5 lbs. pressure deducted from 1514 inches of area, and with the compound engine the lesser area is presented half the time; hence the power of the compound should be greater than that of the simple engine, as we shall probably find.

Correcting for the back-pressure and distribution, the figures would stand:—

$95.44 - 5$ lbs. $= 90.44 \times 378.5 = 34{,}231.5$ for the high-pressure cylinder; and $23.86 - 5$ lbs. $= 18.86 \times 1135.5 = 21{,}415.5$ for the low-pressure cylinder, giving to the high-pressure cylinder an excess of 12,816 lbs. of force.

To equalise the load upon the two pistons of a compound engine it is evident that considerable departure from the rules given must be made.

REVISED CALCULATIONS FOR PROPORTIONING THE CYLINDERS OF A COMPOUND ENGINE.

RULE 2. Ratio between areas of the two cylinders =

$$\frac{\text{Total number of expansions.}}{\text{Ratio of expansion in first cylinder}}$$

= square root of total number of expansions × about 1.5. We have, therefore, with 16 expansions, $\sqrt{16} = 4 \times 1.5 = 6)1514(= 252.33$ inches for the area of the high-pressure cylinder.

The volume of steam to be cut-off in this cylinder = 16)1514(= 94,625 cubic inches; and 94.625)252.33(= 2.666 as the ratio of expansion in the first cylinder, *i. e.*,, steam cut-off at 3/8; and 2.666)16.(= 6, as before found for the ratio between the two cylinders. The hyperbolic logarithm of $2.666 + 1 = 1.979$, and of $6 + 1 = 2.7918$.

For the first cylinder the calculations would be:—

2.666)160.000(= 60 × 1.979 = 118.74, less 5 lbs. back pressure = 113.74 lbs. for the M. E. P.

Then

$$\frac{113.74 \times 252.23 \times 600}{33{,}000} = 522 \text{ H. P.}$$

For the second cylinder the calculations would be :—

6)60(= 10 × 2.79 = 27.9—5 = 22.9 lbs. M. E. P.

The area of the low-pressure cylinder, 1514, less the area of the high-pressure cylinder, 252.33, gives 1261.67 square inches as the effective area of No. 2, and

$$\frac{1261.67 \times 22.9 \times 600}{33{,}000} = 522 \text{ H. P.}$$

Triple Expansion Engines.

A ready way to comprehend the working of a triple expansion engine is to conceive the three pistons superimposed upon one another, as shown in Figs. 3 and 4, and considered as one piston. No. 1 represents the area of

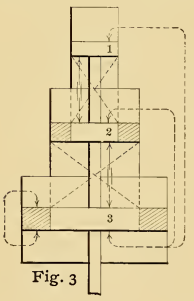


Fig. 3

Fig. 4

the high-pressure piston ; the annular ring, No. 2, gives the area of the intermediate, and the outer ring ring, No. 3, the area of the low-pressure piston, all making one simultaneous stroke. The return stroke completes the full revolution of the triple expansion engine. The initial pressure to the following piston is considered the terminal of its predecessor.

This, however, is not the case, except where receivers are used with cylinders Nos. 1 and 2, and expansion valves are fitted to all three cylinders; otherwise there would be a considerable drop in the steam pressure, in passing from one cylinder to the next, by having to fill the unavoidable clearance and waste space. Besides this there is a further loss, occasioned by the full area of the smaller piston being deducted from the larger one in each case, an inoperative field, in that the steam there is not actively employed in driving the piston, although not entirely lost, as the steam, expanding in this waste space, reinforces the steam acting upon the piston.

To find the correct mean effective pressures upon the pistons, take simultaneous cards from the three cylinders, and lay off upon the first and second the back-pressure line recorded upon the third. The ordinates will count from this added back-pressure line, and not from the back-pressure line traced by the indicator upon the cards in question. The true back-pressure acting against the three pistons is that found upon the exhausting side of the low-pressure cylinder.

Revised Calculations for Proportioning the Cylinders of a Triple Expansion Engine.

Rule 3.

Area low-pressure cylinder = Total horse-power × 33,000 / M. E. P. × piston speed in feet per minute.

Area high-pressure cylinder = Area low-pressure cylinder / Total rate of expansion × decimal point cut-off in high-pressure cylinder.

Area intermediate cylinder = Area low-pressure cylinder / $\sqrt{}$ ratio low to high × by about 1.1.

The area of the low-pressure cylinder, as previously found, is 1514 square inches. Assume a cut-off in the first cylinder of $\frac{7}{10}$ stroke. Expansions 16 × .7 = 11.2)1514.0(= 135 inches for the area of the high-pressure cylinder. Number of expansions corresponding to .7 = 1.428, the hyperbolic logarithm of which + 1 = 1.3506. Then 1.428)160,000(= 112 × 1.3506 = 151.3—5 = 146.3 lbs. M. E. P. for No. 1.

Cylinder No. 2 $= \sqrt{11.2} = 3.347 \times 1.05 = 3.514$ (new ratio). Hyperbolic logarithm $+ 1 = 2.256$. Then $3.514)1514.000(= 430$ inches Area No. 2; and $3.514)112.000(= 31.9 \times 2.256 = 72 - 5 = 67$ lbs. M. E. P. for No. 2.

Cylinder No. 3. Ratio of expansion in cylinder No. $1 = 1.428 \times$ ratio of No. 2; $3.514 = 5.018)16.000(= 3.18$, which is the ratio left for cylinder No. 3; $3.18)31.90(= 10$ lbs. $\times$ hyperbolic logarithm of $3.18 + 1 = 2.157 = 21.57 - 5 = 16.57$ M. E. P. for No. 3. Now, the effective area of No. 3 = 1514 minus 430 =

$$\frac{1084 \times 16.57 \times 600}{33{,}000} = 357 \text{ H. P.}$$

Horse-power of No. 2 = 430 minus 135 =

$$\frac{295 \times 67 \times 600}{33{,}000} = 360 \text{ h.-p.}$$

And horse-power of No. 1 =

$$\frac{135 \times 146.3 \times 600}{33{,}000} = 360.$$

It is now universally admitted that the saving in fuel effected by the compound over the single cylinder engine is about 25 per cent., and that the triple expansion engine has realised a further gain of 25 per cent. upon the compound; but just to what cause to attribute the economic results attained has never been satisfactorily demonstrated. The causes generally assigned are, higher steam pressure, greatly modified initial and working strains, avoiding the excessive variation in cylinder temperature to which the simple expansive engine is subjected; and lessening the evil effects of initial condensation by isolating the high-pressure cylinder from the chilling influence of the condenser.

In preparing this article the writer has been considerably puzzled to account for the invariable gain in power of the compound and triple expansion engine over the simple expansion engine of same size cylinder, 1514 inches area. We find the simple expansion engine to have 900 horse-power, the compound engine 1044 horse-power, and the triple expansion engine 1077 horse-power.

The writer believes that he has discovered a substantial reason for a considerable part of the unaccountable gain, as follows:—The loss from back pressure in the compound engine is reduced to one-half, and in the triple expansion engine to one-third that encountered in the simple expansion engine. This, so far as he knows, he has the merit of being the first to point out. In the simple expansion engine the back pressure reacts upon the full area of the cylinder, 1514 inches $\times$ 5 lbs. = 7570 lbs.

In the compound we have $252.33 + 1261.67 = \frac{1514}{2} = 757 \times 5$ lbs. $= \frac{3785 \text{ lbs.}}{3785 \text{ lbs. and}}$

$$\frac{3785 \times 600}{33{,}000} = 69 \text{ H. P. gain.}$$

In the triple expansion engine we have $135 + 295 + 1081 = \frac{1514}{3} = 505 \times 5 = 2525$ lbs., and 7570 less 2525 =

$$\frac{5045 \times 600}{33{,}000} = 92 \text{ H. P. gain.}$$

In the foregoing calculations the clearance is supposed to be included in the point of cut-off given for the first cylinder and is also included in the bulk of the other cylinders, and the drop is considered nil. The back-pressure has been assumed to be 5 lbs. throughout, with no attempt at special accuracy. In practical working the actual back-pressure may be reduced to 3 lbs.

FIRE-BOATS.

By H. de B. Parsons.

WHEN the fire gong rings in a large city, one is accustomed to see engines rushing along the streets, madly racing to be first in answer to the call. Few, however, realise that in many cities having a water frontage there are also marine engines performing corresponding services. These, many times more powerful than the largest land engines, are under steam day and night, always ready to assist the land forces in fighting their common enemy.

The water front of a large commercial city is immensely valuable for storage and manufacturing purposes, and the value of the buildings and their contents, and that of the docks, vessels and cargoes, represent a vast fortune. As this property is usually of a very combustible nature, the demand for protection has become so urgent as to necessitate in many cases the construction of a fleet of marine engines, or fire-boats.

The utility of these boats is especially marked in connection with the suppression of a fire on a vessel, on account of the great difficulty of effectively fighting such a fire from the shore. Their powers, however, are not limited to this work, since the more powerful boats are able to force effective fire streams through 1500 to 2000 ft. of hose. The boats thus become very valuable aids to the land service.

As the shipping interests developed, many harbour tugs were equipped with fire-pumps and hose in place of the ordinary bilge apparatus, as required by law, and this outlay soon proved to be wise, as was shown by the claims paid for salvage.

However, the importance of still further protection was emphasised by the occurrence of some very extensive fires among the docks and along the waterfronts just beyond the reach of these tugs and too hot to be successfully fought by the comparatively small land-engines, which were often compelled to devote their entire attention to preventing the flames from spreading.

The fire hazards in all large marine cities are much increased because the water frontage usually consists of old and dangerous buildings, located on narrow streets, and largely used for stor-

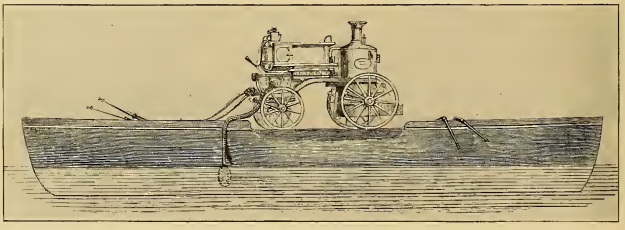


FIG. 1.—A TYPICAL LONDON FIRE-BARGE.

age and warehouse purposes. Many of these buildings are very difficult to reach from the land side, so that it is necessary that powerful pumps be provided to throw water upon the fire from

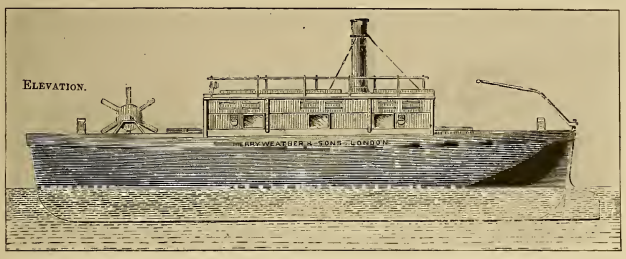


FIG. 2.—A LAND FIRE ENGINE CONVERTED INTO A FLOATING FIRE ENGINE, AS ADOPTED BY THE NORWEGIAN, RUSSIAN AND OTHER GOVERNMENTS. BUILT BY MESSRS. MERRYWEATHER & SONS, LONDON.

a considerable distance. This, too, has helped to gradually develop, as an additional equipment to the fire departments, the system of protection by floating engines.

When it is considered that a large modern fire-boat is equivalent to about nine of the most powerful land engines, the utility of these boats becomes at once apparent; and when allowance is

and $200,000,000 (£30,000,000 and £40,000,000). It has become a matter of record, that by far the greatest loss of property is caused by the numerous small fires that are continually occurring, because those fires which threaten to become destructive conflagrations are usually checked in their infancy. If we assume the dividing line between these two classes at a loss of property valued at about $250,000 (£50,000) the reports of the insurance companies show that only one-fifth of the gross annual loss is attributable to the larger conflagrations. This result

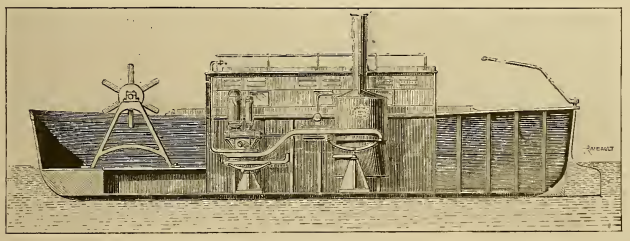


FIG. 3.—SECTIONAL VIEW.

made for the great effect of the big streams from the monitor nozzles, the relative power of these boats becomes even more marked.

The gross annual loss throughout the world by the destruction of property by fire has been estimated by the best authorities as between $150,000,000

is obtained not so much by the better fire-resisting qualities of modern structures, as by the more perfect apparatus in vogue and the organisation of corps of trained and experienced firemen. The most effective systems are those constituted on a military basis, the active force being divided into battalions

FIG. 4.—THE FIRE-FLOAT "ACTIVE," LONDON. CAPACITY 900 TO 2000 GALLONS PER MINUTE.

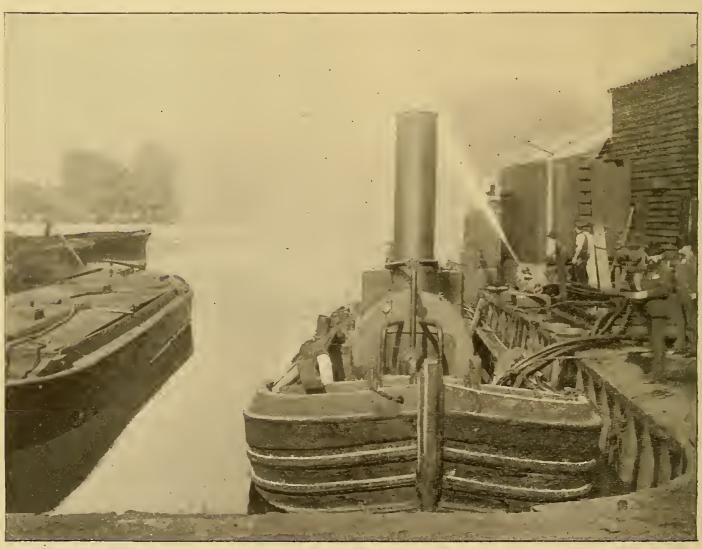


FIG. 5.—AN ENGLISH COMBINED FIRE-BOAT AND DREDGE.

and companies under command of suitable officers, and the whole subordinated to a single head or commission.

It would be beyond the scope of this article to attempt to describe the great fires with which these floating engines have successfully battled, or to mention the many cities which purchased their boats only after having a sad and costly experience. Suffice it to say that the authorities of the world have long since recognised the faithfulness and bravery of the organised crews and the underwriters have acknowledged the efficiency of these floating engines.

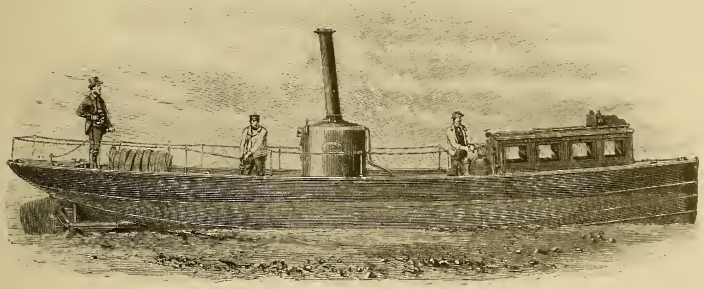


FIG. 6.—FLOATING FIRE ENGINE FOR SUNDERLAND, ENGLAND, BUILT BY MESSRS. MERRYWEATHER & SONS. CAPACITY, 1100 GALLONS PER MINUTE.

As this subject of marine protection is one of such general interest and importance, the author has thought it well to record the gradual development of these floating engines, and to briefly outline the necessary requirements of a modern, high-powered fire-boat. The earliest attempts to supply river and harbour protection were made by placing ordinary land engines upon floats or barges, which were then towed to the scene of the conflagration. The city of London owns about thirteen such barges (Fig. 1). They are made double ended, so as to be easily handled.

The Russian and Norwegian governments adopted a slightly different type of float, as is illustrated in Figs. 2 and 3. These floats were made of iron, about 40 ft. to 50 ft. in length, and 10 ft. in width. An ordinary land engine was lowered by a crane into the float, provided with strong frames to receive the axles, an operation requiring from fifteen to twenty minutes. After the engine was placed and secured, the movable deck-house was fitted over it. Some of these boats ordered by the Russian government were self-propelled by hose jets, placed over the stern. As the pumping capacity of these floats was limited by the size of the land engines, an improvement was made by having the barges permanently equipped, each with its own boiler and pump.

Nine floats of this character, with eight steam tugs, are now owned by the city of London, and distributed at five different stations for the protection of the shipping interests of the River Thames. One of these floats, *The Active*, controlled by the Metropolitan Fire Brigade, is illustrated in Fig. 4. The machinery, which covers a space 20 ft. by 5 ft., is protected by a tarpaulin canopy, which was removed when the photograph was taken. As these floats are flat bottomed and double-ended, they require very little water, and being "snub-nosed," can approach close to the banks at low tide. Their length varies from 40 ft. to 60 ft.

FIG. 7.—THE "WILLIAM S. STOKLEY," PHILADELPHIA. CAPACITY, 2000 GALLONS PER MINUTE.

They lie at anchor at their several stations, accompanied by a tug, always under steam, ready to tow them to the place where required. Under favourable circumstances, their speed is about 7 miles per hour. They are equipped with a pump, boiler and hose. The boiler is of the quick-steaming variety, steam being raised during the passage of the float from its station to the fire. The pumping capacity varies from 900 to 2000 gallons per minute, water being supplied by a fixed suction passing through the bottom of the boat.

Such floats are in use by the authorities of Hamburg, Venice, Marseilles, Constantinople, Odessa, Cronstadt, Shanghai and Yokohama. On account of the trouble incident to a separate tug, the dangers of towing in a crowded waterway, and the difficulty of manœuvring, these floats were still further improved by making them self-propelling.

In 1874, the River Wear Commission, in England, built for Sunderland, the boat shown in Fig. 6. This is an iron vessel, 40 ft. long by 9 ft. 6 in. beam, and draws 24 inches of water forward and 30 inches aft. It is propelled by twin screws, 28 inches in diameter, driven by independent vertical engines. The fire pumps were made by Merryweather, of London, and have a capacity of 1100 gallons per minute. The equipment of fire streams consists of one large jet, 1⅞ in. in diameter, or arrangements to use simultaneously twelve smaller jets. The trial on the Thames before the Metropolitan Fire Brigade was highly satisfactory, as the boat developed a speed of about 10 miles per hour, and showed excellent manœuvring ability. This Commission also built at about the same time, a second boat for use at Durham. This latter boat, which is still in service, is 65 ft. long and of slightly greater pumping capacity.

The more modern floating engines are a marked improvement over the older types. This advance was necessitated by the rapid industrial growth of

many large cities, and was possibly hastened by some costly and destructive fires. Fig. 5 represents an English type of combined fire-boat and dredge, which has proved of great value for service in dock yards and similar places.

In 1875, the city of Philadelphia built the steamer *William S. Stokley*, shown in Fig. 7. The hull was built of steel, and is 96 ft. long, 17 ft. beam, and requires 9 ft. of water. There is one tubular boiler, 14 ft. 6 in. long by 7 ft. 6 in. diameter, carrying steam at 50 pounds pressure. It has one fire pump, with a capacity of 2000 gallons per minute, which supplies four small nozzles and one large monitor jet, 2½ inches in diameter. The water pressure at the pump is 160 lbs. per square inch.

In 1875, the city of New York built its first boat, the *William F. Havemeyer*, which is of wood, 106 ft. long, 22 ft. beam, and draws 10 ft. of water. It is, at present, equipped with a Cowles water tubular boiler with an allowed pressure of 240 pounds, driving a single cylinder, jet condensing engine. It has four duplex fire pumps with a capacity of 2400 gallons per minute, supplying water at 250 pounds, and delivering through nozzles of various sizes from 1 in. to 3½ in. diameter.

In 1881, Philadelphia built a second boat, the *Samuel G. King*, shown in Fig. 8. This is a steel boat, 80 ft. long by 18 ft. beam, and draws 7 ft. of water. The boiler is of the tubular type, 7 ft. in diameter by 7 ft. long, with steam at 125 lbs. pressure. There is one Silsby rotary fire pump, which runs at 650 revolutions per minute, supplying 1250 gallons for use in six jets and one large monitor nozzle of 2½ inches diameter.

In 1882, New York increased its fleet by building the *Zophar Mills* shown in Fig. 9. This vessel was the most powerful boat of its time, being constructed of iron, 125 ft. long, 25 ft. beam, and having a draft of 9 ft. 9 in. The main engine consists of a single inverted, surface condensing cylinder, supplied with steam at 60 lbs. from two flue and return tubular boilers, each 8 ft. 6 in. wide by 13 ft. long.

The fire apparatus consists of two duplex and one single pump, all of the vertical, crank and fly-wheel pattern.

FIG. 8.—THE "SAMUEL G. KING," PHILADELPHIA, CAPACITY, 1250 GALLONS PER MINUTE.

The water pressure is 250 lbs. There are three stand-pipes with 1¾ in. nozzles, and 12 other outlets. The boat has power enough to operate simultaneously about 13 streams, and has actually pumped water into a tank a mile away to supply four land engines. The pumping capacity of the boat is about 5500 gallons per minute, and it has attained a speed of about 13 miles an hour.

Chicago built in 1883 a boat named

FIG. 9.—THE "ZOPHAR MILLS," NEW YORK. CAPACITY, 5500 GALLONS PER MINUTE.

W. H. Alley, which name, in 1887, was changed to *Chicago*. The boat is of wood, 90 ft. long, 18 ft. beam, and its draught is 8 ft. 6 in. There are two fire pumps, having a total capacity of 2200 gallons per minute. In the same year, Philadelphia ordered a third boat, known as the *Visitor*. This boat, shown in Fig. 11, was smaller than the others, being 75 ft. long, and contained two double-acting fire pumps, serving three streams of 2½-inch diameter at 300 lbs. water pressure.

In 1886, five boats were built, one for Alexandria, Egypt; one for Brooklyn; one for Chicago; one for Buffalo; and one for Cleveland. The first of these, the *Merryweather*, shown in Fig. 10, was built in London for the Egyptian government, and when tested at Westminster before the Metropolitan Board of Works, previous to its shipment, was much admired by all who saw the experiments. It is 51 ft. long, 10 ft. 6 in. beam, and draws 4 ft. of water. The hull is of iron with division bulkheads, and is equipped with towing gear, so that the boat can be utilized as a tug. The main engine is of the two-cylinder inverted type, operating a three-bladed screw, which gives a speed of 9 miles per hour. The fire equipment consists of a direct-acting double cylinder pump of Merryweather's Admiralty pattern, having a capacity of 1500 gallons per minute. The delivery pipe has seven outlets through the deck. The centre one is 3½ inches in diameter, for use with a 2-inch jet, and the others are arranged for 2¾-inch hose with ⅞-inch to 1½-inch nozzles. This boat has proved of very great value to

FIG. 10.—THE "MERRYWEATHER," BUILT FOR THE EGYPTIAN GOVERNMENT BY MESSRS. MERRYWEATHER & SONS. CAPACITY, 1500 GALLONS PER MINUTE.

the Egyptian government, and has extinguished many serious fires, some of incendiary origin, that threatened the destruction of Alexandria.

The second boat, built by the city of Brooklyn, was the *Seth Low*, shown in Fig. 12. It is of wood, 99 ft. long, 23 ft. beam, with 7 ft. 6 in. draught. The boat is manœuvred by twin screws, driven by inverted engines, surface condensing without a vacuum. There is one Scotch boiler, 9 ft. 3 in. in diameter by 14 ft. in length, carrying steam at 100 lbs. pressure, and operated both by forced and natural draught. The fire equipment consists of two du-

FIG. 11.—THE "VISITOR," PHILADELPHIA.

FIG. 12.—THE "SETH LOW," BROOKLYN. CAPACITY, 3470 GALLONS PER MINUTE.

plex pumps, supplying water at 250 lbs. per square inch to 12 streams using 3½-inch hose, and one bow nozzle 3 inches in diameter. The illustration shows this bow nozzle in operation. It has thrown a stream through a 3¼-inch nozzle a distance of 427 ft. The pumping capacity is 3470 gallons per minute.

The third boat was the *Geyser*, shown in Fig. 13, built by order of the fire department of Chicago. This boat is of wood, 109 ft. long, 24 ft. beam, with 9 ft. draught of water. The main engine is of the non-condensing, double cylinder, inverted type. Steam of 100 lbs. pressure is supplied by one Scotch boiler 11 ft. 5 in. diameter by 16 ft. in length. There are two vertical, duplex fire pumps, having a capacity of 3000 gallons per minute, operating against a water pressure of 130 lbs. This boat has shown a speed of over 17 miles an hour, and was designed especially for working in the thick ice that forms in the Chicago river during the winter months. On the trial test this boat threw four 2-inch streams a distance of 249 ft.; one 4-inch stream, 386 ft.; and fourteen 1¼-inch streams, 204 ft.

The *George R. Potter*, shown in Fig. 14, of Buffalo, the fourth boat, is 80 ft. long, 20 ft. beam, and draws 7 ft. of water. The hull is strongly constructed of steel, and is driven by a double-cylinder, inverted, high-pressure engine, the cylinders being 16 inches in diameter by 18 inches stroke. There is one Scotch boiler, 11 ft. by 11 ft., generating steam at 100 lbs.; also two duplex pumps, capable of working at 300 lbs. pressure, and having a capacity of 4000 gallons per minute. There are connections for ten fire streams with 1¼-

inch nozzles, seven with 2-inch, and one with 3-inch nozzles.

The *Cataract*, of Cleveland, shown in Fig. 15, made the fifth boat, and was built of wood, 79 ft. long, 22 ft. 8 in. beam, with 8 ft. 4 in. draught of water. The equipment consisted of a single-cylinder, inverted, non-condensing main engine, a Kunstadter steering and propelling screw, 6 ft. in diameter by 9 ft. pitch ; a Scotch boiler, 10 ft. in diameter by 14 ft. in length, furnishing steam at 100 lbs. pressure. There are two vertical, duplex fire pumps, having a capacity of about 3800 gallons per minute. The speed of the boat on its trial trip was about 10 miles an hour.

It will thus be seen that the year 1886 showed a very marked improvement in supplying this much-needed form of protection against fire. The power of these vessels will be better appreciated when it is considered that their combined capacity is sufficient to throw 3970 tons of water per hour, or to pump dry a tank 100 ft. long by 100 ft. wide by 13 ft. deep in the same time ; or that each of the American boats is as powerful as seven or eight large land engines. As a matter of record, the success of the boats just described led to a very large increase in the demand for still further protection.

In 1889, Chicago added to its fleet the *Yosemite*, a wooden vessel of the same dimensions as the *Geyser*, with the exception that the draught is 11 ft. 6 in. The boiler is of the flue and return tubular type, 10 ft. wide by 14 ft. long. The two fire pumps have a capacity of 3300 gallons per minute, this being slightly greater than in the case of the *Geyser*.

In the same year, Boston constructed the first of its present fleet, known as *Engine No. 31*. This boat, built of wood, is 108 ft. in length, 24 ft. 6 in. beam, and 9 ft. draught. It is propelled by a fore-and-aft, compound, condensing engine, steam being supplied at 118 lbs. pressure from two vertical, submerged tubular boilers, 7 ft. diameter by 12 ft. high. The fire equipment consists of two vertical, duplex, crank and fly-wheel pumps, having 16-inch steam and 9-inch water cylinders, both of 10-inch stroke, discharging 6000 gallons per minute through eight outlets for 2½-inch hose and four for 3½-inch hose. There are also, in addition, two large stand-pipes for throwing 4-inch streams. This boat was very carefully tested by Mr. William Jackson, City Engineer, with the following result :—The maximum discharge through both stand-pipe nozzles, with a water pressure of 87.9 lbs. at engines, which were running at 304 and 285 revolutions per minute for port and starboard, respectively, was 6043 gal-

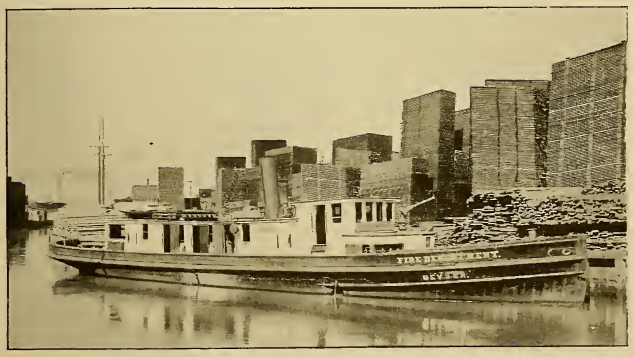


FIG. 13.—THE "GEYSER," CHICAGO. CAPACITY, 3000 GALLONS PER MINUTE.

lons per minute. The maximum water pressure obtained was 170 lbs. These tests are probably the most complete ones that have ever been made on the efficiency of a fire-boat, and to Mr. Jackson and his associates are due the thanks of all interested in this subject.

In 1890, New York constructed the most powerful boat that has ever been built. This boat, called *The New Yorker*, is strongly made of steel, is 125 ft. long, 26 ft. beam, and 11 ft. 6 in. draught. Unfortunately, the draught is about 30 inches more than was originally intended, which accounts for the "squatty" appearance of the boat as shown in Fig. 17.

FIG. 14.—THE "GEORGE R. POTTER," BUFFALO. CAPACITY, 4000 GALLONS PER MINUTE.

It is propelled by a triple-expansion engine, with steam at 148 lbs., supplied by two Scotch boilers, 12 ft. in diameter by 15 ft. long. One of these boilers is capable of operating the boat, while the other is held in reserve. There are four sets of vertical, duplex, crank and fly-wheel pumps, and one small single direct-acting pump.

The water pressure is 300 lbs., and the deliveries consist of 32 outlets, including four large stand-pipes. The pumps can easily keep twenty fire streams at play, and have a capacity of about 12,000 gallons per minute. As originally constructed, the boat had a Kunstadter steering screw, but it was changed a short time ago for the single screw arrangement, because it was found that the vibrations were so great as to shake the rivets loose in the stern frame. The crew are comfortably quartered in a house on the boat's dock, and the boat, together with its house, probably forms the most complete equipment of any marine fire station in the world.

Baltimore, in 1891, built a wooden boat, called *Cataract*, having a length of 85 ft., 18 ft. beam, and drawing 9 ft. of water. The main engine is of the compound, condensing type. Two water tube boilers, of the Cowles design, supply steam at 175 lbs. pressure. There are two vertical, duplex fire-pumps, giving a water pressure of 200 lbs., and discharging about 5000 gallons per minute. The boat is equipped with eight outlets for 1⅜ inch nozzles and one for a 3-inch bow tower. Fig. 19 represents this nozzle in place, and

FIG. 15.—CLEVELAND FIRE-BOAT "CATARACT," BUILT BY MESSRS. THOS. MANNING, JR., & CO., CLEVELAND, O., U. S. A. CAPACITY, 3800 GALLONS PER MINUTE.

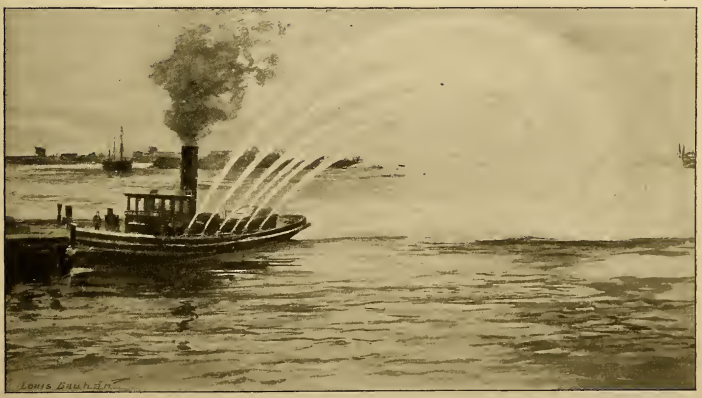


FIG. 16.—THE "DAVID A. BOODY," BROOKLYN. CAPACITY, 5500 GALLONS PER MINUTE.

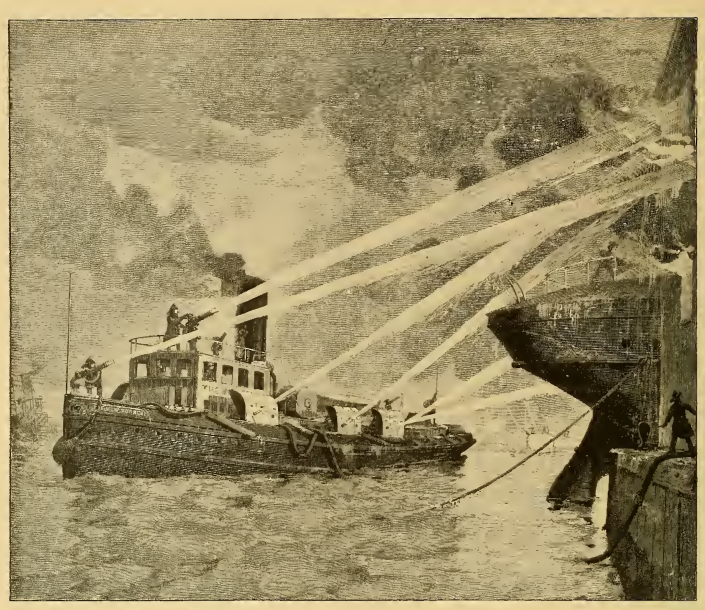


FIG. 17.—THE "NEW YORKER," THE MOST POWERFUL FIRE-BOAT EVER BUILT. CAPACITY, 12,000 GALLONS PER MINUTE.

shows the general form and method of operation. Similar water towers are fitted on the Brooklyn, Philadelphia, Baltimore and other boats.

In 1892, Chicago built its fourth boat, the *Fire Queen*, which is 80 ft. long, 16 ft. beam, and draws 3 ft. 6 in. of water. This is much the smallest of Chicago's fleet. It is equipped with two direct-acting pumps and one rotary engine and pump, having a total pumping capacity of 1800 gallons per minute.

During the same year, Buffalo also ordered the *John M. Hutchinson*. This vessel is of the same length as the *Fire Queen*, but of greater beam and draught. It has a pumping capacity of nearly 5000 gallons per minute, using eight streams of 1¼-inch diameter, five

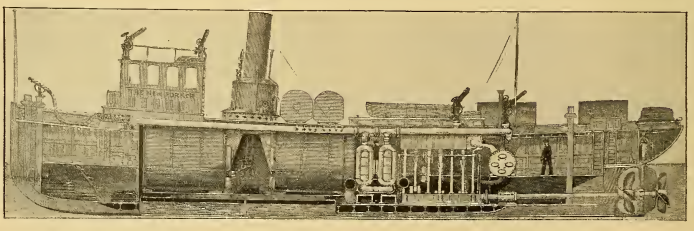


FIG. 18.—SECTIONAL VIEW OF THE "NEW YORKER."

of 2-inch, two of 2½-inch, and one of 3½-inch.

It will be noticed that both of the Buffalo boats have two stand-pipes in the bows instead of one. This equipment makes the boats especially useful on the Buffalo Canal, which is lined on both sides with grain elevators and other valuable structures. Slowly working ahead, the boats can attack simultaneously, from the front deck, fires located on each bank; or, on windy days, can use one stream on the fire itself and the other to prevent the spreading of the flames.

Brooklyn also added to its service the *David A. Boody*, shown in Fig. 16. This is a wooden boat, 105 ft. long, 23 ft. 9 in. beam, 8 ft. draught. It is driven by a compound condensing engine, and has a flue and return tube boiler, 10 ft. 3 in. in diameter by 14 ft. long, generating steam at 130 lbs. pressure. There are two duplex pumps, affording a water pressure of 250 lbs., and capable of discharging about 5500 gallons per minute through eight outlets for 3½-inch hose and one bow tower having a 3-inch nozzle.

After the *Merryweather* had arrived

FIG. 19.—A FIRE BOAT WATER TOWER, DESIGNED TO THROW STREAMS FROM 2½ TO 5 INCHES IN DIAMETER. OPERATED AND CONTROLLED BY ONE MAN. MADE BY D. A. WOODHOUSE, NEW YORK.

at Alexandria, the cotton merchants of that city ordered built, in 1893, a novel type of floating fire engine, shown in Fig. 20. This vessel was constructed of steel, 60 ft. long, 10 ft. 6 in. beam, with 18 inches draught. It contains one water tube boiler, and Merryweather's pumps, of the Greenwich pattern, having a capacity of 2000 gallons per minute, delivering to six 3½-inch outlets, fitted three on each side, and to one large 4-inch jet.

The main feature of the design is that the boat is hydraulically propelled by jets. By means of a sluice valve, the delivery of the pumps is discharged through these jets, which are capable of giving a speed of about 5 or 6 miles an hour in smooth water. These jets can be operated by hand wheels from

FIG. 20.—HYDRAULICALLY PROPELLED MERRYWEATHER FIRE-BOAT FOR EGYPT. CAPACITY, 2000 GALLONS PER MINUTE.

FIG. 21.—THE "EDWIN S. STEWART," PHILADELPHIA. CAPACITY, 6000 GALLONS PER MINUTE.

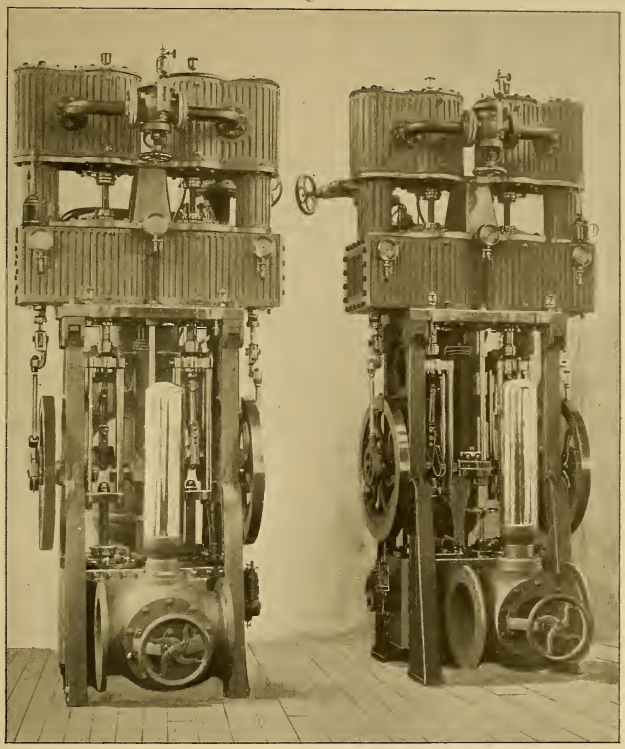


FIG. 22.—VERTICAL COMPOUND FIRE-BOAT PUMPS, BUILT BY THE AMERICAN FIRE ENGINE CO., SENECA FALLS, N. Y., U. S. A.

the deck, so as to manœuvre the boat in all directions and thus assist the rudder. The boat is of special value for service on the Mahmoudieh Canal, and reports concerning it have been most satisfactory.

During the same year, Philadelphia completed its fleet of four steamers by the addition of the *Edwin S. Stewart*, shown in Fig. 21. This boat is one of the most powerful in service, being comparable only with the two Boston boats and *The New Yorker*. Its length is 110 ft., beam 23 ft. 7 in., draught 9 ft. 9 in. It has a compound engine, and a Cowles water tube boiler. The pumps are two in number, of the vertical, duplex, crank and fly-wheel type, delivering water at 300 pounds pressure to 8 streams and one monitor bow nozzle 3½ inches in diameter. They have a combined capacity of over 6000 gallons per minute.

Last year, Boston built its second boat, known as *Engine 44*. This is a wooden boat, 110 ft. long, 26 ft. beam, 8 ft. 6 in draught. The main engine is compound and either condensing or non-condensing as may be required. There are two vertical boilers, with submerged tubes, 7 ft. 6 in. diameter by 12 ft. 6 in. in height. The pumps

are of the vertical, duplex, compound, crank and fly-wheel type. There are twelve outlets for 3½-inch hose in addition to three stand-pipes. This boat also was tested by Mr. Jackson with the result that 6420 gallons were discharged per minute from the two bow nozzles alone.

The following table gives a summary of the boats owned by the different cities:—

Name of City.	Number of Boats.			Total capacity in gallons per min.
	Wood.	Iron or Steel	Total.	
Al'x'n'ria, Egypt	--	2	2	3,500
Baltimore	1	--	1	5,000
Boston	2	--	2	12,463
Brooklyn	2	--	2	8,970
Buffalo	--	2	2	9,000
Chicago	4	--	4	10,300
Cleveland	1	--	1	3,800
London	22	--	22	16,500
New York	1	2	3	19,900
Philadelphia	--	4	4	10,000
River Wear	--	2	2	2,250

It will be seen that the most powerful boats are located at Baltimore, Boston, Philadelphia and New York. While London makes a large showing in the table, it must be remembered that it is caused by the great number of floats which the city owns. As these floats are able to throw streams of only small diameters, they are not as effectual fire fighters as the other boats. These floats, together with the accompanying tugs, probably cost as much, if not more, than the more modern self-propelling vessels, which latter have the still further advantages of being self-contained, without division of the crew, and are capable of towing a burning vessel into the stream, out of danger to other vessels and docks, while still throwing fire streams.

Generally speaking, fire-boats should be located at the most convenient points of vantage, so as to command the greatest extent of property, consideration being given to distances, the value of property to be protected, and the risks of fire. The boat should be connected to the department headquarters by telephone, and also to the system of fire calls adopted. These connections are made by having the electric wires worked into a flexible cable, which can be quickly and easily slipped in case the vessel has to leave her station.

The pilot house should be so designed as to command a view in all directions, to serve as an office, and to protect the captain and pilot when the boat is in action at a fire. The coal capacity of the boat should be sufficient to allow considerable length of time to elapse before it is required to refill the bunkers. In many cities, it is convenient also to have quarters for the men on board, but this is not always necessary. Where the lodging place is near the station, the crew can be summoned by an electric gong, or some other similar means of call.

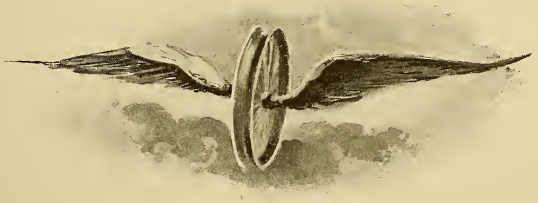
There is some diversity of opinion as to the most approved designs for pumps, but best practice seems to favor the vertical condensing types. Fig. 22 shows the compound pumps of Boston boat, No. 44. The diameter of the high pressure cylinders is 12¾ inches, of the low pressure 18 inches, and of the pump cylinders, 10 inches, all having a 11-inch stroke. The distributing apparatus should be simple, easily reached for repairs, and arrangements made either to concentrate the streams in a few large jets or in a number of small ones, according to circumstances. The siamese connections are found very useful in this particular, as they can be screwed on a large discharge outlet and the stream divided into two smaller ones. The large monitor jets are made in sizes, varying from 2½ inches to 5 inches in diameter. These nozzles or tips can be quickly changed, as the size to be used is entirely controlled by the number of the other outlets in use, the water pressure not being sufficient for a very large jet when many lines of hose are being operated.

It has been found that streams from nozzles less than 1¼ inches in diameter are inefficient against a hot fire, and that one large stream is much more useful than the same quantity of water

divided into smaller ones. Provision, however, should be made for many small streams, as there are cases, as for instance, in preventing the spread of a conflagration, when it is necessary to use them, so as to attack the fire simultaneously at many points, and to keep the adjoining property thoroughly wet. It has also been proved that boats exceeding 110 feet in length are unhandy for fire service. This is especially true in cities having long slips or situated on narrow and crooked rivers.

For manœuvring purposes, some of the boats have been made with twin screws, but the extra ability in turning power has been offset by the complication of the machinery and the increased floor space that the engines require. Out of the twenty-one self-propelling boats above mentioned, only two were designed with twin screws, one with side jets, and eighteen with single screws.

For similar reasons, a speed exceeding about 14 miles an hour does not seem to be of great value, unless the boat is situated under peculiar conditions, requiring trips to distant points. Even then, it would pay to build two boats. Water tubular boilers are giving promise of greater use in the future, but of the boats mentioned, only three were fitted with such boilers, while eighteen have the fire tubular type.



AMERICAN NAVAL ENGINEERS: THEIR RANK AND TITLES.

By Wm. Ledyard Cathcart.

"WE can only repeat that the undue subordination of the engineering branch in an engineering navy is fraught with the gravest possibilities of danger to the State." These are the editorial words of one of the foremost engineering journals of our time; and yet, the conditions which they describe and deprecate exist to-day within the United States naval service. Its organisation is based on the methods of the past.

The officers of the line are probably without superiors as artillerists and navigators, but they are amateurs purely with respect to detailed knowledge of the complicated mechanisms for propulsion, ordnance service, and many other varied purposes which fill modern ships. The engineer officers of the United States Navy, like the line officers, are educated at Annapolis, and form a highly skilled and scientific corps; but their number is most inadequate to their heavy and increasing burden of work and responsibility, and they labour, in addition, under a cumbrous and antiquated organisation, the relic of pre-Rebellion days.

The defect in the United States naval system which contributes most seriously to impair the efficiency of the corps of engineers is the absence of positive military rank for its officers. Years ago, as a partial settlement of a long-pending controversy, the corps received from Congress the concession of so-called "relative" rank, but while this step gave its officers all the privileges of those of the line in quarters, pay, and precedence on courts-martial and ceremonial occasions, it was found that, when put to the crucial test of command, this quasi-rank was a vague and elusive thing.

The proper function of relative rank is simply, and only, to determine the precedence of officers of separate services who meet on ceremonial occasions; further than this it cannot go. The line and the engineer officers of the navy constitute one service; "their joint action is for the consummation of the same purpose; they are inseparably one as regards their naval duties." There cannot be two kinds of rank in any one organisation; rank there may differ in degree, never in kind. In the navy positive or military rank must exist, and, hence, relative rank, which differs from it in kind, is, for it, a logical impossibility,—like the surd in mathematics, an "irrational quantity."

It is safe to say that the legislators who framed this statute did not contemplate the results which were to follow. In the House of Representatives, Mr. Stevens, who had the bill in charge, made the following statement:

"Substantially there were but two points of difference between the two Houses upon this question. The first was in regard to whether the staff corps of the navy should have actual rank in conformity to the law regulating the staff corps of the army, or whether it should be an assimilated, imperfect, inchoate rank or a fixed, positive, actual rank; and I think that it was the opinion of the committee that had it in charge that this bill conferred upon the staff of the navy the same rank and official position that are enjoyed by the staff corps of the army, at least the same corresponding position. That was the purpose of this bill."

This purpose has not been carried out. That so vital a portion of the force as is the engineer corps should be

left without absolute command over its own men, that its legal status in the exercise of its most important function should be open to question, is more than an absurdity. The effect has been to leave between an illogical law and the lax naval regulations which attempt its interpretation a wide debatable ground, the practical limits of which, under varying conditions, can be, perhaps, best illustrated by quoting the Duke of Wellington's brilliant and arrogant dictum as to martial law, which he defined as "the will of the commander-in-chief."

When that commander-in-chief, as Captain, if the vessel be acting singly; as Admiral, if she be on a distant station; or as Secretary of the Navy, if she be nearer home, has been gifted with broad patriotism and keen mental vision, the engineer officer has been untrammeled; with the reverse, the friction has been constant. The effect of such conditions on the *morale* of the officers and men of this corps can be fully understood only by those familiar with the routine of a military organisation. That, despite them, the discipline and efficiency of the force have been maintained is a notable tribute to the tact, strength of character and superior intelligence of its officers.

The objections urged in the past against the giving of positive rank to the engineer officer were mainly that his field of duty was restricted; that the size of his force afloat was relatively small; and, finally, that according to military law he was a non-combatant. With the changed conditions which prevail, it would seem difficult, at this time, to present even a *prima facie* case in support of these propositions. The vital importance, the varied nature, and the wide range of his duties and usefulness may be shown by a single extract from the Naval Regulations:—

"He shall, from time to time, make inspection of machinery under cognisance of other bureaus and report * * any repairs or adjustment which in his judgment may be needed. He shall have immediate charge of all such repairs. * * * He shall perform such other professional duties as may be assigned him."

In other words, in addition to the powerful propelling engines and their dependencies which he controls, this officer inspects and keeps in repair all other machinery of every kind and for every service. Again, an examination of the complements of modern ships of war will show that, in commerce destroyers of the *Columbia* class, his force comprises one-half of the combatant strength of the ship; and, in armoured cruisers of the *New York* type, fully one-third of this number. And, finally, as to his non-combatancy, it may be said that this definition was made in the days when physical prowess was the main element in warfare. The changes of this age render necessary the revision of military law on this point.

Ships are no longer laid yard-arm to yard-arm in what the Great Admiral called the "Nelson touch," while boarding parties surge to and fro above, and the sanded decks below, lit by the lurid glare of battle-lanterns, run red with the slaughter from roaring broadsides at close range. The musket and the pike, the battle-axe and the grappling iron have been honourably retired from naval warfare; the sword of the officer has become but a badge of rank; and, in our time, the naval action has been transformed into a duel at long range, behind armoured walls, with weapons of precision,—the tools of the engineer.

While this change has been, to some extent, a gradual one, it was effected finally through the *Monitor*, the first of American ironclads. When she came from the hands of Ericsson,—in hull, turrets, armour, and machinery, a complete conception,—that finished engineer, in thus producing a vessel impregnable to attack by boarding, rang the knell of personal combat on the sea and laid down, as well, a new definition of the combatant. The true sea-fighter in this day is he who is essential to the military strength of the ship.

The primary function and the ultimate object of a naval fleet is warfare. In considering the status of the engineer in action, let us assume that the line branch of the vessel be divided into a navigating, or executive corps, composed of the commander

and his immediate aids, and an ordnance corps which shall fight the battery. The cardinal duties of the battle-ship are to reach her field of action, to effect which she needs only the navigating and engineer corps; to manœuvre and attack with artillery on that field, in which all her corps are required; and, finally, to attack directly by ramming, when, as in the first instance, the ordnance corps is not needed. It will be seen that in all these combatant functions the engineer is an absolute essential and that in one only will there be required the ordnance corps, which branch would, of necessity, include a far larger proportion of the line than the relatively small navigating corps.

With regard to the danger of the engineer officer's post in action, it has been said that he is below the protective deck, as if peace and safety slept within its shadow. As a matter of fact this deck is a relatively thin shell, depending for its resistance mainly on the angle of incidence of the shot; and, further, being below that deck and within a closed compartment is, in itself, a situation to try, at such a time, the nerve of most men.

It is told of Farragut, that, when making, near Vicksburg, during the American Civil War, a reconnoissance in an ironclad, he soon grew impatient with the narrow bounds of the casemate and, "for safety," went on deck, where shot and shell fell thickest. As with him, most brave men prefer to fight in the free air,—not in a confined space, in tropic heat, and with artificial light and ventilation, especially when that light and air may, in a moment, vanish with a well-aimed hostile shot. Again, that protective deck will not ward off the danger from the torpedo or the submarine boat, which strike below the armour belt; nor, indeed, from even light gun-fire if the ship be so heeled over as to show her thin hull plates. On this latter point, a recent writer says:—

"A list of ten degrees would expose the plates below the armour, and, in this way, a battle-ship might be sunk by the rapid-fire gun of a torpedo chaser or a gunboat. Anything happening to boilers or bunkers on one side might cause this list." And, finally, when we recall the tragedy of the *Victoria*, we realise, perhaps, the engineer's greatest danger from without. Rammed,—but not at high speed nor in action; not in a gale, but on a placid sea, and in the full light of a June afternoon,—that battleship, in sinking, carried with her five of her six engineer officers and two-thirds of their force. Of this, *Engineering*, of London, said:—

"Undoubtedly, in a case such as this, the heroism of the occasion is with the engine-room staff. * * * That the engineer officers and men of the *Victoria* braved these dangers in the discharge of their duty and went to what they must have known was certain death, forms one of the most noble pages in the glorious annals of the British Navy."

It is not only external attack which makes the engineer officer hazard much in action. With heavy machinery, driven at excessive speed, with boilers and piping put to their utmost stress, his immediate surroundings have within them the elements of grave and sudden danger. The power of steam at the pressures now used,—160 to 240 lbs.,—makes it, when misdirected, terrible in its destructiveness. Concussion, from gun-fire or ramming, will develop any latent weakness in joints, piping, or bracing.

A single instance will show what this may mean:—On the German battle-ship *Brandenburg*, in 1894, "the stop-valve on the separator broke short off, close to the flange, thus giving a full opening to the escape of steam from the twelve boilers. The door between the two engine-rooms was open, and, of the men in them, 39 were killed outright and 9 so badly injured that 6 of them died subsequently."

In view of the wide field of service of the engineer and of the large proportion of the force which he controls, it seems a strange anomaly, in a navy whose *matériel* is wholly engineering, whose every vital function has its source

in, and its application mainly through, him, that this officer should still be ranked as a non-combatant. The tradition of a vanished past obtrudes its shadow to cloud his arduous service, his great responsibility, the overwhelming importance and inherent danger of his post in action.

There is a marked parallelism between the duties of the naval, and those of the army engineer. The officers of the latter branch form the designing, and with their sappers, miners, and pontoniers, the constructing, arm of that service. Despite the fact, however, that, except by executive authority, they shall not assume nor be ordered on any duty beyond the line of their immediate profession, their combatant status has been recognised from the first. As an outgrowth of, and not an addition to, the line of the army, they have met no opposition to their military rank and title. In professional attainments these officers are regarded as the corps d'élite of that service.

Further, there is a close analogy between the action of an artillery force, which by massed and heavy fire, prepares the way for the charge of infantry in battle, and that of the engineer corps of a vessel in so manœuvring her that her ordnance officers shall be enabled to train her guns effectively upon her opponents. In the naval, as in the military example, one corps supports the other; neither acts singly; success depends upon both. And, finally, in that direct and most terrible of all assaults,—ramming, the service of the engineer corps seems identical in principle with that of a charging column of land forces.

While there are many minor instances of this mode of attack in the American War of the Rebellion, with one noble and notable one by Farragut, at Mobile bay, the terrific effect of a charge by rams in squadron or fleet,—the cavalry of the sea,—seems to have been strangely overlooked in these days of complicated battleships. On this point, one of the most accomplished American officers of the line and one of its ablest strategists as well, says :—"The simplicity of the ram, and, when properly built, her actual impregnability to any gun-projectiles, with her turning powers in half the time of other vessels of the same length and displacement, reduce a fleet of battleships, in the presence of a fleet of rams of the same number, to little more than helpless war canoes."

It will be seen, that, viewed from any standpoint, either directly or by comparison, the duties of the naval engineer officer are essentially combatant and military. To class him as a member of the civil branch is a misnomer. Civil officers take no part in military operations and are not called upon by the nation to risk life in its cause. Justice to him requires that he be given positive military rank in due recognition of his service; and wisdom imperatively requires it, in view of the relatively large force of men which he must organise, instruct, and direct in peace, and which, in battle, amid grave dangers and sudden emergencies, he must control in the performance of functions vital to the ship.

With this military rank should come also the replacement of the professional titles of engineer officers by those of their lineal grade. While such a great American constitutional lawyer as Senator Edmunds maintains that the law as it now stands gives to the staff a legal claim to such (lineal) titles, still, as with the rank, this statute is vaguely drawn and the right of the staff to them should be clearly established.

Military titles, as now employed in the line of the navy and in the army, have but two functions—to indicate the fact that the officer is a member of the naval or military service and to mark his grade in that service. They have no reference to professions and convey no information as to whether the officer is an artillerist and navigator in the navy or an ordnance officer, an engineer, or a surgeon in the army. The military idea is not capable of combination with the professional, and immemorial usage makes a title referring to the latter, inconsistent with a combatant service. If, in the passing of the years,

other military officers than the line have been added to the navy, there seems no valid reason why that corps alone should bear the titles which are, in justice, the right of all.

In view of the changes which have come so swiftly in the *matériel* of the navy,—changes which have revolutionised, in a few brief years, its whole fabric and which have made a battleship but a mighty machine, built up of many minor mechanisms,—it seems inevitable that there should be, as well, marked changes in the naval personnel. A full recognition of the corps of engineers and the making of that branch a strong and powerful body seems the first step; but this should be supplemented by a radical departure in the training of line officers.

When all officers, both of the line and staff, are, in the performance of duty, handling mechanism, all should be, to a greater or less extent, acquainted with its design, construction, and conservation. The great commanders of the future will be men, who like the gallant and honoured Admiral Ammen, combine, with stout hearts and strategic brains, an intimate knowledge, based on engineering study, of the details and capabilities of the mass of machinery which constitutes that floating fortress, the war-ship of to-day.

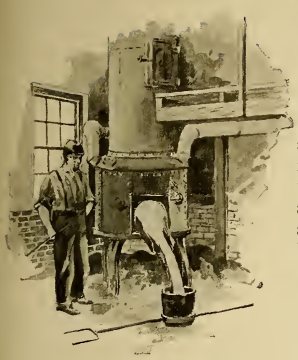
The time-honoured but now obsolete naval organisation, struggling with the management of modern *matériel*, recalls forcibly the words of the distracted Hecuba, when during the fall of Troy, she saw its old king, Priam, tottering forth to battle with the armour of a stalwart warrior upon his wasted frame,—

"*Non tali auxilio, nec defensoribus istis tempus eget.*"

And so it seems that "not such aid, nor such defenders, does this age demand." The desire of every thoughtful citizen that the naval personnel shall be a united and powerful body, should be echoed in the wish and reflected in the act of every officer in that service. Country should come before corps, and class-interest follow, not precede, the welfare of the nation. If "positive rank" for the corps of engineers means unbroken ranks in the force which shall some day face the foe, there should be found no officer of the Navy to oppose its enactment.

ECONOMICS IN THE FOUNDRY.

By C. O. Heggem.



PROBABLY, no department of an engineering establishment responds more readily to the touch of order and systematic administration, by turning out better work at less cost, than the foundry. Not that this department is any more ready and waiting for the work of the reformer than some other departments; far from it.

The obstacles and prejudices to be overcome are numerous, for it is here, as everywhere else, considered as a sacred duty to oppose anything that is new, and it is, indeed, surprising with what determination this opposition will be carried out, even when it is tolerably easy to see that the proposed change will be as beneficial to the employed as to the employer. On the whole, the foundry will show a saving by the adoption of improved methods, quicker and in greater proportion than any other department. It is, of course, essential that whatever reform is introduced should be along practical lines, for there is nothing that so destroys faith in improvements as those which fail to improve; and, for this reason, it is well to study the case in hand from all possible sides, to make sure that no vulnerable spot can be found anywhere. If this has not been done, the weak spot will be there, and it will be found, too; for there are a great many more people looking for it than there are people looking for, and willing to show up, the merits or good points in any new scheme. It may be that this is strictly in accordance with the law of "the survival of the fittest," and, if so, real improvements have nothing to fear from it.

It is the purpose of this paper to deal with the foundry from an administrative point of view, to show how an order for work appears, and follow it through its travels until returned to the place from which it started. The system here outlined has been in use in one of the largest foundries in the United States for a number of years with excellent results; and, while it was gotten up to especially meet the requirements of a large plant, it will be found to be as well adapted to small ones, inculcating order and neatness, with all their attendant virtues, wherever introduced. It forms part of a complete system, comprising the whole establishment, which, described in its entirety, would exceed the space allotted to this article. Enough, however, will be seen from the following pages to show how it is applied to the foundry.

A shop-order is authority for all machinery made. This order emanates from the main office. In the present case, *Shop Order No. 267* calls for 80 6 x 9 x 10 compound traction engines. From this order are made up the specifications for the different departments, and blank *B 31* is for the foundry. It answers the purpose of specifications to the foundry foreman for all castings required to complete the order, and is furnished to him with each shop-order. In order that the foreman may not be unnecessarily taken up with clerical labour, and that he may be enabled to spend most of his time in the foundry, where his serv-

ices are the most valuable, this blank is so arranged that he can assign each piece to the workman he deems proper, and, after having assigned the moulding of the various parts, his assistant writes up individual orders on blanks, promptly filling them, and that they are accompanied by patterns and follow-boards. The cores are delivered to the moulder on his floor by the core-maker who made them, and the piece-work price of each core covers such

B 31 Engine Order No.

Shop Order No. 267

Jan. 3 1896

Dep't B—Furnish Dep't 9 Supt.

The following Castings For 8 ½ - 6 × 9 × 10" Compound Traction Engines

CHECK	SYMBOL.	NAME OF PIECE.	Total Ordered.	Stock On Hand.	TO WHOM ASSIGNED.	CHECK.
✓	D1849	Engine Bed and H.P. Cylinder	80	12	Mr. Miller	
	D1855	L.P. Cylinder	80		H. Lee	
	D1856	L.P. " Head	80	7	Jas Brown	
	D1853	Distance Piece	80		F. Rice	
	D1695	Cylinder Brackets	80		E. Rumely	

B-26, to each moulder named, writing one order for each part to be made.

These orders are then delivered to the core-maker, who makes up his order for the cores and assigns them to his men in the same manner. The delivery. Core-makers are paid only for such cores as are actually used each day.

Moulders are allowed to reject any and all cores which in their judgment are not perfect or properly made, and

B26-10M-7-95. B 26

S. O. No. 267 To Mr. Miller Date Jan. 3-96

E. O. No. Transferred to Date

F. O. No.

Make Castings as follows and Tally number of Pieces made and Scrapped each Day.
All Castings scrapped from any cause to be replaced without further order.

	No. Pieces Ordered.	Symbol & Number.	NAME OF ARTICLE.	TOTAL
	68	D1849	Engine Bed and Cylinder	
Tally	2 2 2 2 2 1 2 2	2 2 2 1 2 2 2 2 2 2 1 2 2 2 2 1 2 2 2 2		50
Castings	2 1 2 2 2 2 2 1	2 2 2 2 2 1		25
Made				75
In these				7
Spaces.				68
TALLY CASTINGS SCRAPPED.	1 1 1 1 1 1 1			7

Workmen MUST keep accurate account of all work assigned them on this card. Castings made in excess of orders will be DISCOUNTED. Examine Symbol and Number on Pattern and see that it agrees with order. Make no work without an order. This order MUST be returned to the OFFICE and Patterns sent out as soon as completed.

orders, *B–26*, then go to the man in charge of the pattern storeroom, who delivers the patterns and follow-boards to each moulder on his floor with the order.

It will be noticed that the orders do not reach the moulder until all necessary arrangements have been made for such cores are not paid for. When imperfect cores are used, and defective castings result from their use, the moulder, having taken all responsibility, is charged with them. When the order is completed, pattern and order are placed at the head of the moulder's floor, and before blast time they

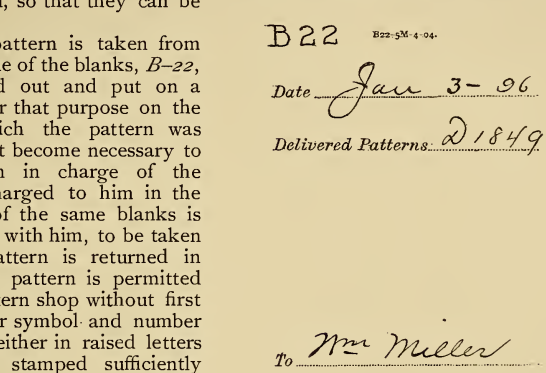
are returned to the pattern storeroom and foundry office, respectively, and checked off on the specifications as filled.

The pattern storeroom is arranged with tiers of shelves, which are subdivided into small sections, each of which is numbered and lettered. Each tier of shelves is provided with a book, listing all patterns belonging on such shelf or tier, and locating the same, as per small section, so that they can be readily found.

Whenever a pattern is taken from the storeroom, one of the blanks, *B–22*, is properly filled out and put on a hook provided for that purpose on the section from which the pattern was taken. Should it become necessary to repair a pattern in charge of the moulder, and charged to him in the storeroom, one of the same blanks is filled out and left with him, to be taken up when the pattern is returned in either case. No pattern is permitted to leave the pattern shop without first having its proper symbol and number placed upon it, either in raised letters and figures, or stamped sufficiently deep to plainly appear on castings made from it, and a record having been made of it. These symbols and numbers are obtained from the drawing room, and appear on all drawings as well, and reference to any pattern is made by symbol and number on all orders for castings or patterns. This system also applies to all miscellaneous patterns, such as shop tools, jigs, boring bars, foundry clamps, flask parts, crabs, etc.

The symbols used are letters of the alphabet, and each letter represents a particular size or variety of machinery. For instance, *A* may be the symbol of all patterns pertaining to threshing machines; *D*, of all 10-inch stroke engines; *W*, of 27-inch stroke engines; *M*, saw-mills, and *X* to all miscellaneous patterns. The numbers follow the symbol in consecutive order, as, for instance, *D 1845*, low-pressure cylinder for 10-inch stroke compound engine. These symbols and numbers are of great use in keeping account of and delivering to the proper department, and storing, castings, as well as handling the patterns, and especially core-boxes, as each core-box is also marked with the symbol and number of the pattern to which it belongs.

All moulding is done by the piece, and each moulder is credited with the full amount of work rammed up on the day on which it is completed. The next day all defective castings are gath-



ered together at one place in the foundry, inspected, and charged back to the party responsible for them, and at the end of each pay interval they are reported to the timekeeper as discount. In like manner, all castings which pass the cleaning department, and are found to be defective only when being machined, are returned to the foundry at stated intervals to be inspected both by foreman and moulders. As the cleaning of castings is nearly all done by the piece, any undue tendency on the part of the moulder to turn out rough work receives a check by a complaint from that quarter.

All castings made are weighed as soon as ready to deliver from the cleaning room, and from the weight book (which deals with them by symbol, number and weight, only) they can easily be charged to the proper department. In order to arrive at the foundry cost of castings, the cupola is charged with all iron and fuel used

B 85 [B 85-1M-3-95.]

DEPARTMENT.....

.....189

Repair Order No.....

.....Foreman. .....Dept.

Make at once and deliver the following, with this order to

.....

Order filled and returned.....189...

Fill this Blank with Labor and Stock.	No. Hours.	Rate.	Total.	
Total.				

Foreman.

each day, this being weighed, and is credited with all castings weighed, and weight of the sprues and all scrap castings weighed back. A separate account is made of all castings made for shop use, and those retained for foundry use are easily kept account of, since no castings are permitted to be made by the moulder without an order, and these orders, being checked up as soon as filled, make it impossible to overlook such items as clamps and gaggers, of which no account is usually taken.

New flasks, flask repairs, blacksmith and all work on foundry appliances, excepting patterns and core-boxes, are ordered from the proper department on order blanks *B–85*, common to all departments, and when the work is done the orders are returned to the department making the order, with labour and material used noted on them, thereby furnishing each department with sufficient data for a monthly report of incidental expenses—an item usually overlooked, or, at best, underestimated in the foundry.

Blank *B–40* is another form of order common to all departments. It is used in ordering goods usually kept in stock, either at the stock room or tool room. The foundry does not use this form as much as some of the other departments, but as it is impossible to obtain anything without an order, this one comes in for such occasional requisitions as the foundry may make for finished goods, on which no labour is spent by the department delivering them.

In a foundry employing not more than 150 men, one man as an assistant to the foreman can easily attend to the necessary bookkeeping, and all other clerical work, as well, and make a monthly report of operations, from which, in connection with the pay-roll and foundry merchandise account, the main office can readily determine just what their castings are costing per pound. This course, if followed monthly for a period of, say, two years, will furnish a permanent factor of incidental expenses, and any radical increase or decrease from this factor at any time would call for immediate attention. This factor would be especially valuable for comparisons when making changes in the administration of that department, or adopting new appliances.

B 40 [B40-20M-4-95]

Foreman's Order.

Date.....189....

Department.....*Deliver to Bearer.*

.....

.....

.....

.....

.....

.....

Chargeable to.....

Foreman.....

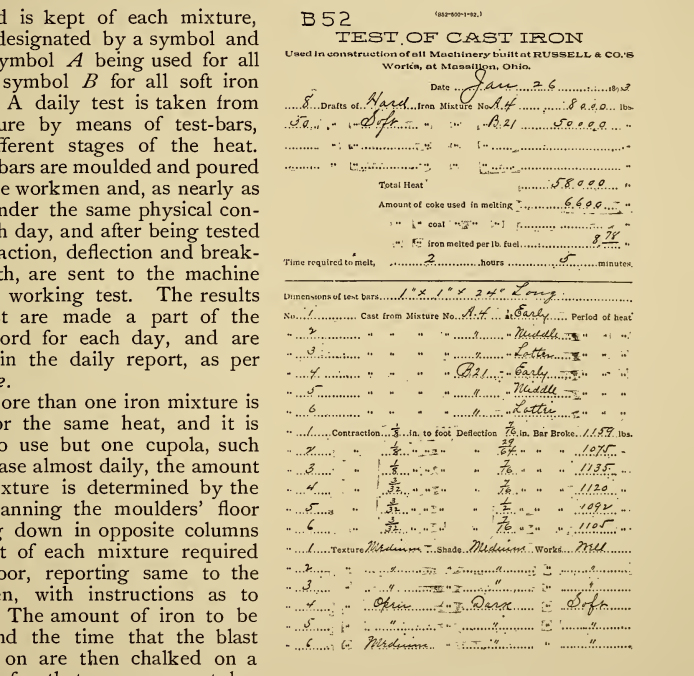
The pig iron is taken from the yard, broken, weighed, mixed and charged into the cupola by two men at a fixed price per ton. The iron is mixed on a four-beam charging scale, arranged with indicators outside of the beam box, so that, after the indicators have been arranged by the foreman for his mixture, the beam box is locked up, and the weigher cannot change the weights or know the proportion of each kind of iron used in the mixture.

A record is kept of each mixture, and it is designated by a symbol and number, symbol *A* being used for all hard, and symbol *B* for all soft iron mixtures. A daily test is taken from each mixture by means of test-bars, cast at different stages of the heat. These test-bars are moulded and poured by the same workmen and, as nearly as possible, under the same physical conditions each day, and after being tested as to contraction, deflection and breaking strength, are sent to the machine shop for a working test. The results of this test are made a part of the cupola record for each day, and are embodied in the daily report, as per blank *B–52*.

When more than one iron mixture is required for the same heat, and it is desirable to use but one cupola, such being the case almost daily, the amount of each mixture is determined by the foreman scanning the moulders' floor and jotting down in opposite columns the amount of each mixture required for each floor, reporting same to the cupola men, with instructions as to charging. The amount of iron to be charged and the time that the blast will be put on are then chalked on a blackboard for that purpose, put between the cupolas, so that everyone, having due notice, can gauge his work accordingly.

As it is fully understood that this time, once fixed, will not be changed, except in cases of dire necessity, it becomes a rare occurrence that all are not ready at the appointed time, and it seldom becomes necessary to have anyone in the shop after working hours, which is duly appreciated by the workmen.

The iron, as it comes from the cupola, is apportioned to the moulders by the foreman and his assistant, and no moulder is permitted to get his iron without having been called upon. Should he have a variety of work on his floor, requiring iron of each of the several mixtures, he is instructed what part of his work to pour, thus making sure that all work is cast from the



B 52 (852-600-1-02.)

TEST OF CAST IRON

Used in construction of all Machinery built at RUSSELL & CO.'S Works, at Massillon, Ohio.

Date ... Jan 26 ... 18 93

8 ... Drafts of ... Hard ... Iron Mixture No. A 4 ... 8 0 0 0 ... lbs.
Soft ... " B 21 ... 50 0 0 0 ...
" ... " ... " ... "
" ... " ... " ... "
Total Heat ... 58 0 0 0 ...
Amount of coke used in melting ... 6 6 0 0 ...
" " coal " " ... 8 ¼ ...
" " iron melted per lb. fuel ... 8 ¼ ...
Time required to melt, 2 hours 5 minutes.

Dimensions of test bars ... 1" x 1" x 24" Long

No. 1 ... Cast from Mixture No. A 4 ... at Early ... Period of heat
" 2 ... " " " " " 3 ... " Middle ... " "
" 3 ... " " " " " 4 ... " Latter ... " "
" 4 ... " " " " B 21 ... " Early ... " "
" 5 ... " " " " " 11 ... " Middle ... " "
" 6 ... " " " " " 11 ... " Latter ... " "
" 1 ... Contraction ... ⅛ in. to foot Deflection 7/16 in. Bar Broke. 1189 lbs.
" 2 ... " ¼ " " " 2/4 " " " 1074 "
" 3 ... " ¼ " " " 7/16 " " " 1135 "
" 4 ... " ⅜ " " " 7/16 " " " 1120 "
" 5 ... " ⅜ " " " 4/16 " " " 1092 "
" 6 ... " ⅜ " " " 7/16 " " " 1105 "
" 1 ... Texture Medium ... Shade Medium ... Works Mill
" 2 ... " " " " " " " "
" 3 ... " " " " " " " "
" 4 ... " Open ... " Dark ... " Soft
" 5 ... " " " " " " " "
" 6 ... " Medium ... " " ... " "

M B Fox

proper mixture and at the most favourable stage of the heat, thereby insuring a more even grade of castings.

The moulders are required to deliver their castings at the foot of their floors, along each side of the gangway track, with sprues broken off, whence they are taken, on the following morning, to

the cleaning room by two gangs of men and trucks. As fast as castings are removed, the gangway sand is also cleaned up and delivered to the core room to be used again, and in a comparatively short time the shop assumes a neat appearance, not usual at any time in many foundries. As rubbish of any kind is not permitted to be thrown upon the floor, general neatness soon becomes a habit among the workmen.

Shelving for patterns and tools at the end of each floor, a good, tight cupboard for clothing, lunch, etc., and plenty of room to store his flasks and boards, leaves him no cause or excuse for untidiness. The flasks and boards are all delivered to him on his floor, and removed as soon as he is done with them and stored systematically in the yard, the larger ones within the radius of a crane and the smaller ones piled up in double rows, with room between for trucks.

Hydrants are placed at short intervals all over the foundry, and each moulder is furnished with a sprinkling-pot. In addition, each moulder is supplied with a shovel, rammer, a riddle, suitable for his work, a hammer, rapping bars, strike-off, draw screws, a casting hook, sponge pot, dust bags, vent wires, a small 18 x 18 parting sand riddle, and a good tool box, with which he is charged when receiving it and credited when turning it over again upon leaving the service. Any of the above tools, when worn out, can be exchanged for new ones or be repaired. Careful and prompt attention to the moulders' wants is the rule, and reforming service and creating discipline becomes an easy task as soon as the men realise that it will gain for them the same facilities and recognition accorded to machinists and other trades. This much accomplished, economical use of material and a better grade of work follow as a natural consequence.

A large proportion of the labour in making cores can be accomplished by boys of from fourteen to sixteen years of age. Of these, several of the brightest are selected each year for apprentices, and advanced at the end of their second year to bench moulding, to be followed by ordinary floor work or machinery moulding, according to the ability developed. In this manner, undesirable men can be weeded out as occasion may require, or men leaving the service of their own accord can be replaced with resident men, familiar and in accord with the requirements of the shop—an advantage which can hardly be overestimated.

The apprentices are not required to sign a written contract. The agreements are all verbal, but experience has shown them to be fully as satisfactory as if they were written agreements. The penalty for leaving before the term has expired is that no certificate of completed apprenticeship is furnished, and this, together with fair chances to get at the different grades of work, and, thus, become proficient in the trade, has made runaways very few, indeed.

The following instructions are general, and are sent to foremen of other departments, as well as the foundry; they cover all the essential points of the apprenticeship arrangement, and, after years of operation, do not seem to need any additions or modifications:—

Instructions Concerning Apprenticeship.

Please note the following rules, governing apprentices in your department:—

The full term of apprenticeship shall be three (3) years. Each year shall consist of three hundred (300) working days of ten (10) hours each.

The compensation shall be ——— per hour the first year; ——— per hour the second year; and ——— per hour the third year.

The change in rate shall not take place until a full working year of three hundred (300) days shall have been completed.

Apprentices above the age of eighteen (18) years may, when the occasion requires it, work extra hours, and will be paid for same at their regular rate, but such extra hours will not be counted

to shorten their term of apprenticeship; neither will short time, in case your department is running less than ten (10) hours per day, be allowed to lengthen the term beyond three hundred (300) actual working days faithfully put in, as per requirement of your department.

Apprentices may do work by the piece, when they will receive 33 per cent. of regular piece work prices for the first year, 50 per cent. for the second year, and 75 per cent. for the third. This percentage shall be determined after the regular discount to which piece work in your department is subject shall have been made.

At the conclusion of the term of apprenticeship, a testimonial, alluding to character, ability, and manner in which the term was filled, will be given.

——— ———, Gen'l Supt.

AN HISTORIC ELECTRIC CENTRAL STATION.*

By John W. Lieb, Jr.

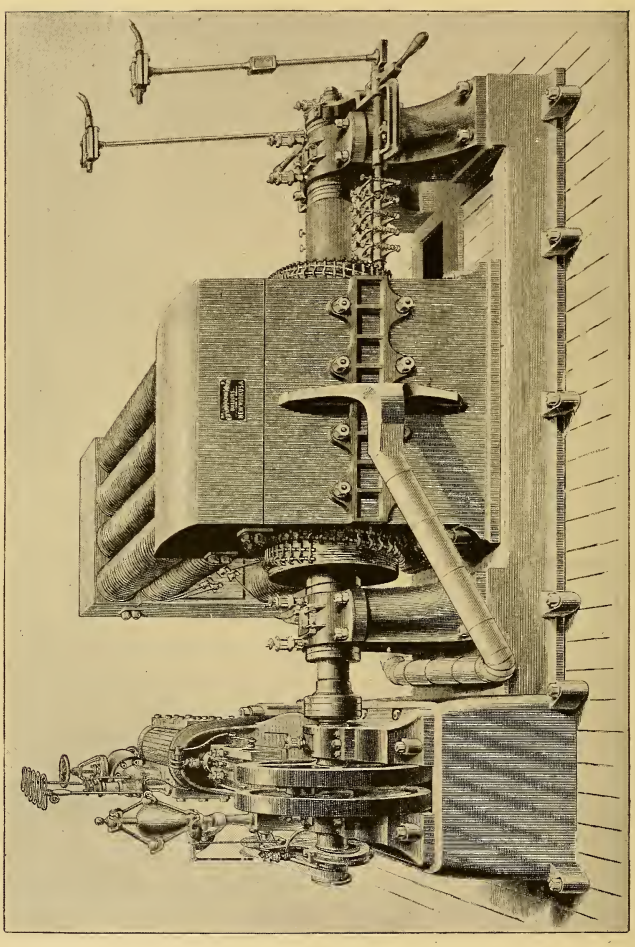
ON the afternoon of September 4, 1882, a small group was gathered in New York city, at 257 Pearl street, awaiting the approach of 3 o'clock. Orders had been given that a circuit breaker of one of the Edison "Jumbo" dynamos should be closed at that hour, establishing, for the first time, connection between the station "bus" bars and the underground system, thereby formally inaugurating the service of the first central station in the United States equipped for the commercial supply of current for light, heat and power through a complete system of underground conductors and interior wiring.

At the offices of Messrs. Drexel, Morgan & Company, on Wall street, were gathered a group of prominent financiers and enthusiasts centered around that interesting and original figure, Thomas Alva Edison. All were awaiting eagerly the "bursting into glory" of the incandescent lamps distributed throughout the offices, signaling the realisation, at last, of the hopes and dreams of confident capitalists and enthusiastic disciples of the "wizard of Menlo Park."

To appreciate the enormous progress that has been made in industrial applications of electricity within the past 15 years, it may prove interesting and instructive to take a look into that historic station and examine the details of its electrical and mechanical equipment. No better idea of the status of the electric lighting industry at the time the Pearl street station was opened for service can be given than by quoting the following extract from the first annual report of the Edison company for isolated lighting, dated November 21, 1882:—

"When this company was formed a year ago, the business of isolated lighting was entirely undeveloped, and no data existed whereby the future development of the business could be foretold. At that time Mr. Edison was making but one size of isolated dynamo, namely, the 'Z' dynamo (60 lights). We had no reliable steam engine; the innumerable details relating to installations, such as fixtures, safety catches and other appliances, were still unperfected, or were not manufactured on a suitable scale. There had been but eight isolated plants installed or in process of installation, and but one or two of them were in operation. We had no force of employes beyond a few connected with the New York office

* Extract from a paper read before the New York Electrical Society.



THE EDISON JUMBO DYNAMO, 1881. ONE OF THE FIRST EXAMPLES OF DIRECT-CONNECTED UNITS.

of the company, and but little preparation had been made for the development of the business. Such was the condition of the isolated business when the company was formed.

"One of the first things done by the company after its business had been systematised, was to take up the subject of procuring additional dynamos besides the 'Z' dynamos, and also suitable engines. At a meeting of the board of directors, held January 26, 1882, the subject of additional sizes of dynamos was discussed, and arrangements were made with Mr. Edison for the construction of experimental dynamos of additional sizes. The result was the production of two commercial dynamos in addition to the 'Z' dynamo, one being known as the 'L,' or 150-light dynamo, and the other as the 'K,' or 250-light dynamo. Arrangements are now being made for the construction of a still larger dynamo for isolated lighting, probably one of 350 lights. Regarding engines, great difficulty was experienced in obtaining an engine adapted to our especial needs."

To that time—October, 1882—the company had installed in all 123 plants, with a total of 21,998 lamps. Among these were several of considerable size, and a few small central stations in country towns like Appleton, Wis., Shamokin and Sunbury, Pa., Brockton, Mass., etc., all of which were supplying current through overhead systems. Such was the state of the incandescent lighting industry when the Pearl street station was about ready for operation.

Fires were built under the boilers for the first time on June 29; the first dynamo was started July 5, and it was tested on a bank of 1000 lamps in the station July 8. Then followed a period of tests and experiments which kept Mr. Edison and his assistants busy day and night, the public press meanwhile being filled with all kinds of wild rumors in explanation of the delay in lighting the district.

In examining the prominent features of this historic plant, we shall find, in one form or another, the essential elements of the best modern practice in central station construction. While it is true that some of the apparatus was crude and elementary in form as compared with present types, it amply demonstrates Mr. Edison's phenomenal anticipation of, and provision for, the broad lines which have made the Edison system so successful.

The station, as at first projected, occupied the premises 257 Pearl street; 255, which was to serve for furture extension, was temporarily used as a store room and shops for the underground department. To prepare the building for the reception of machinery, a heavy iron structure of girders and columns, not unlike the elevated railway structure, was set up, the boilers being below, and the engines and dynamos resting on the girder platform above. The steam plant consisted of four Babcock & Wilcox boilers of 240 horse-power each, with the necessary equipment of steam pipes, heaters and feed pumps; coal and ash conveyers and a blower for forced draught completed the equipment and auxiliaries. The engine equipment, as originally planned, consisted of six Porter-Allen engines, 11 1-16 inches by 16 inches, each of which developed a maximum of 200 horse-power at 350 revolutions. The dynamos were of the old "Jumbo" type, one of the first examples of direct-connected slow-speed units, each having a capacity of 750 ampères at 120 volts when running at a speed of 350 revolutions per minute.

The conditions imposed upon the engines were so severe that but few engine builders dared attack the problem. High piston speed, close regulation, accurate balancing, limited space and great strength required to stand the sudden applications of load, made the use of the ordinary engine impossible. A number of types of engine were therefore especially developed for this work, at least two of which are still recognised in the market as standard types of construction.

In the preliminary tests of the engines and dynamos while under load, unexpected difficulties developed in connection with the operation of the

steam dynamos in parallel. There was a continual tendency to shift the load from one engine to the other, a see-sawing of the governors and great variations of speed, accompanied by brilliant pyrotechnic effects, that threatened the destruction of both engines and dynamos—a difficulty partially overcome by coupling the levers of the governors to a common rock shaft. Eventually Armington & Sims engines were developed, which completely solved this difficulty, and this type replaced several of the Porter-Allen engines.

The armatures of the "Jumbo" dynamos were 27 inches in diameter and 61 inches long, and each weighed nearly 10,000 pounds; the copper armature bars weighed 590 pounds and the armature disks 1500 pounds. Each machine had 12 field magnets, of which eight were connected to the upper pole-pieces and four to the lower; the copper wire on the magnets weighed 1500 pounds, and the total weight of the magnetic circuit was something over 33,000 pounds. The base plate weighed 10,300 pounds, the dynamo 44,800 pounds, the engine 6450 pounds, making the total weight of the complete unit 61,550 pounds. The progress made in dynamo construction since these machines—which were considered marvelous in their day—were built is shown by comparison with a modern slow-speed multipolar dynamo, which, of approximately the same capacity, weighs only one-fifth as much, occupies but one-third the floor space, and has a much higher efficiency. The "Jumbo" dynamos heated seriously, and the commutators sparked viciously under full load, and it was necessary to use an air blast to keep the temperature down.

It will doubtless cause surprise to learn that the Pearl street station was started and operated for some time without a single voltmeter or ammeter; in fact, the station switchboard, the central keyboard from which the modern station is controlled, was altogether absent in this case. The dynamo and distributing switches, field regulators, etc., were located without any attempt at centralisation. The voltage was maintained with fair approximation from the indications produced by an electro-magnet connected across the circuit, the armature of which carried a contact lever playing between high and low contacts, the pull of the magnet being balanced against an adjustable spiral spring. These contacts closed a relay circuit having a red and a blue lamp, the red lamp lighting when increased voltage gave the pull of the magnet the ascendancy, and the blue lamp when the voltage dropped so as to give the spring the advantage. This apparatus was carefully graduated and adjusted by comparison with the electro-motive force of a standard battery.

The station "bus" bars were built up of the half-round copper bars of the Edison two-wire tubes, and the main dynamo switches—ponderous affairs, as big as hay-cutters—established connection between the dynamos and the "bus." The "bus" bars extended to the Pearl street end of the station, and from this point copper lugs, carrying safety catches, distributed the current to the feeders entering the Pearl street vault. The field regulators for each dynamo were built up of 40 or 50 large resistance boxes wound with strands of copper wire. They were so colossal that the regulators for the six dynamos, together with the connecting shaft and gear for operating the switch quadrants separately or together, took up nearly the entire floor above the dynamo room.

The underground system of mains and feeders—then of the two-wire system—had a length of about 18 miles.

The Edison underground tubes for the two-wire system differed from the present type in having two conductors of nearly semi-circular section, instead of the three copper rods used in the three-wire system, and were separated by paraffined cardboard disks, instead of spirally-wound jute rope before filling with compound. The coupling joints of the 20-foot lengths were made of solid copper loops instead of stranded cable. At the time of laying the

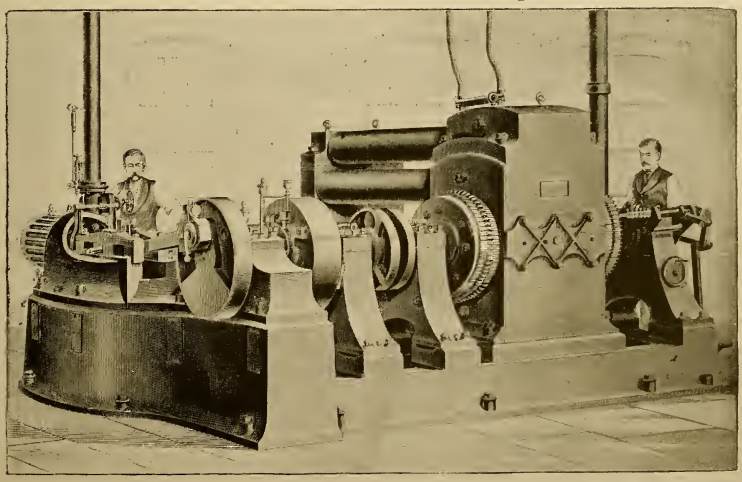
underground system, many of the tubes of large and small conductor section were bent by a special machine to the angle necessary to overcome the obstacles encountered in the streets, instead of using angle boxes, and many of the faults that developed in the early days were due to contacts in these bends.

In laying out the first district and determining the number and location of the feeders, a model of the district was prepared to scale, small spools, with resistances proportioned to the number of lamps, indicating the number of important installations. Wires, representing the system of mains, were drawn along the block faces and connected at the corners, thereby forming a complete network. The location of the feeder connections was experimentally determined by actually sending current into the spools and wires and locating, by actual measurements with a galvanometer, the most favourable points of connection to give an approximately uniform distribution of potential over the system.

Much of the interior wiring was cleat work, and I am sorry to say that the dangerous iron staple was also in evidence. Many of the first installations were equipped with wire having paraffined cotton braid insulation, but nearly all of this wire was replaced before the current was turned on the system.

From the beginning, Mr. Edison considered the meter one of the essential elements of a system for commercial supply of current for light and power, and, as soon as the station was started, arrangements were made to introduce the Edison chemical meter. The first bills based on the amount of current consumed, as shown by the meter, were rendered after the station had been in operation a few months.

The Edison lamps in use at that time were of eight candle-power (two in series, of 50 volts each), 16 candle-power and 32 candle-power, with an efficiency of 4⅔ watts per candle. On October 1, 1882—as stated, the station was started September 4,—59 customers, having an installation of 1284 lamps, were connected; this number was increased on January 1, 1883, to



A LATER FORM OF EDISON DIRECT-CONNECTED GENERATOR, ARMINGTON & SIMS ENGINE.

231 customers, with 3477 lamps connected, and wiring had been installed for 5328 lamps.

At the time the first lighting district in New York was canvassed, great importance was attached to the probable use of current to operate electric motors, and a map was prepared showing the location and capacity of all steam and power plants in the district. It was not until 1884, however, that motors were connected with the system. The first arc lamp was connected to the system in 1889.

Such was the old and historic Pearl street station and the district it supplied, and such it continued, with slight additions and changes as experience was gained, and increased demand for current suggested improvements, until destroyed by fire in January, 1890.

THE WASHING OF GOLD PLACERS IN SOUTH AMERICA.

Otto F. Pfordte, M. E.

HYDRAULIC NOZZLES.

THE comparative abundance of gold in placer deposits and cheapness of working the same in many localities on the earth have always made this method of obtaining the precious metal one of special interest to mankind, and it may safely be stated that up to within the last three or four decades by far the largest proportion of gold was produced by this method.

It is highly probable that the gold possessed by King Solomon was obtained from deposits of this character. It is well known that the fabulous wealth of the great Inca race, who had attained a high degree of civilisation in the Western half of South America before the conquest by the Spaniards, was obtained entirely from this source. Their wealth in the precious metal was so great that the last Inca, Atahualpa, when imprisoned in Cajamarca by the conquering Spaniards, could readily promise as a ransom for his liberty to fill a room 24 ft. long by 17 ft. wide with gold to a height of 9 ft., a promise which was practically fulfilled.

The boundless wealth found by the Spaniards in Cusco, Pachacamac, Jauja and other places all proved the existence of enormous gold deposits in the newly discovered country, which were subsequently worked, but by no means entirely exhausted, by the conquerors. The great discoveries of gold in the United States during the middle of the present century also owed their prime importance to the fact that they were gravel deposits, which permitted the extraction of gold with comparatively simple methods.

Placer deposits may be described generally as mountains or gravel banks, varying from 5 or 10 ft. to 250 or even

400 and 500 ft. in height. They consist of grains of sand, pebbles of various sizes and large boulders, the presence of the latter, however, adding considerably to the difficulty in working a deposit. Sometimes, as found in certain localities in California, the gravel deposit is covered with a layer of volcanic rock or lava, in which case drift mining must be resorted to, and most of the advantages of placer mining are lost.

In most instances the gold is found in a certain class or strata of gravel which are generally distinct from the barren overlying sections, and can readily be distinguished by the experienced miner. The famous gold-bearing blue gravel of California is a good example of this characteristic condition. The gravel banks are sometimes traversed by barren strata of loam or clay; and, again, it is not uncommon to find parts of the gravel which are considerably enriched. This latter condition is more particularly found near the bedrock where the small gold nuggets enter into the cracks and crevices and often form a welcome bonanza to the miner.

The gold which occurs disseminated through the auriferous sections of a gravel bank varies from small particles, called "colours," of almost microscopic size, to large nuggets weighing several ounces and even pounds, not to mention those historic nuggets which weighed over 100 pounds, and in themselves brought fortunes to their owners. The value of gravel in the United States is estimated at so many cents per cubic yard. Thus a gravel deposit producing six cents per cubic yard is considered fairly profitable when operated on a very large scale; gravel giving from twelve to fifteen cents per cubic yard is operated at a good profit with a fair water supply. Sometimes, but rarely, the gravel is worth fifty cents, a dollar, or more per cubic yard, and in such cases a good location means a fortune to the lucky miner.

The special character of the grains of gold in one deposit is often quite distinct from that found in another location. In most cases the difference is in the general shape, some being flat and thin, others rounded off, others irregular and curly. In some cases the outer colouring, taken from the gravel, shows a distinction, and thus an experienced miner is able to state with considerable accuracy from which placer a certain sample of gold came.

The placer deposits of greatest extent are not infrequently found at or near the foothills of large mountain ranges, as the Rocky mountains in California, the eastern slope of the Andes mountains in Peru, pre-eminently in Sandia and Caravaya, or the western slope of the Andes, as in Ecuador, generally varying in altitude from 3000 to 9000 ft. above sea level. There are, however, numerous instances in which profitable placer deposits, though of smaller extent, are located in high plateaux or valleys between the mountain ranges, at a height of from 14,000 to 17,000 ft. above the sea.

Though all of the large placer deposits may be considered as being in their original position, many of the smaller deposits, especially along the river banks, are not in their original location, and may then properly be called secondary placers. These are also formed occasionally by the sudden action of a large quantity of water upon a gravel bank, which may be caused by an earthquake, the sudden overflowing of a lake by the bursting of its natural dam, or the breaking up of an ice gorge. These secondary deposits are generally low, varying from only a few feet to perhaps 20 or 30 feet in height, and occasionally cover a large area of the valleys in which they are found. The river diggings are, of course, generally small, and in most cases limited by the immediate neighbourhood of the rivers.

The methods of working gold deposits differ very much according to the intelligence and means of the operators, the general location of the deposit and its water supply, and the available dumping ground for the washed gravel, called debris. An ideal gold deposit is one of considerable extent, containing the precious metal in paying quantities, without very large boulders, with an unlim-

ited water supply at high pressure near the deposit, and facilities for disposing of the debris, either by dumping into a neighbouring valley or a rapidly-flowing river.

It is, however, extremely rare that all these favourable conditions are fulfilled in one place, and those lacking will have to be provided, often at a heavy expense, when operations are to be undertaken on a large scale. When, on the contrary, work is to be done on a small scale, especially by the methods generally pursued by the Indians in South America, then the necessary conditions, though still the same, are reduced in proportion, and can be provided with far greater facility.

The simplest apparatus used by the natives is the wooden gold pan, or batea, which holds about twenty pounds of gravel, and is taken to the nearest water pool or brook. The larger pebbles are carefully washed and thrown out by hand, and then, by a peculiar swinging motion, the remaining sand and gravel are washed off, the soiled or lost water being occasionally replaced by a fresh supply, until finally the "colours" of gold remain, accompanied by a small amount of other heavy material contained in the gravel, generally oxides or sulphides of the heavier metals. This mixture is then placed in a separate vessel until the final clean-up at the end of the day's work is made. Sometimes a little mercury is added to prevent the loss of minute "colours." This process is necessarily very slow, and only a very skillful operator is able to wash from 200 to 250 bateas per day.

Another crude, but much better, method consists in dividing a small shallow box into several partitions, filling the latter with fine roots or moss, and allowing water from a small brook or ditch to flow over them. By discharging the auriferous gravel just above the box, the sand and pebbles will be washed over by the water, and the particles of gold, becoming entangled in the roots, remain. The roots are then washed in the batea at the end of the work.

Another method is by means of the cochada, taking its name from cocha, a lake. It consists of a small water reser-

THE PIPE LINE OF THE PLAYA DE ORO COMPANY.

A PROFITABLE GRAVEL BANK.

voir having a sluice gate near its bottom. The reservoir is filled gradually by a small brook, and when full the gate is opened, the water passing over and washing the gravel, which has previously been placed in a paved sluice below. This method is generally employed in secondary placers, where the surface is almost level except at the low face of the gravel bank.

A method employed in river washings consists in placing numerous flat stones edgewise, obliquely down the stream, often covering many hundred square feet. When the river rises during the rainy season, the waters sweep over this pavement with the sand and gold, depositing the latter behind the stones. At low water the Indians come to these places, remove the stones and wash the gravel in the batea.

After the conquest of South America the Spaniards operated those enormous deposits by more civilised but still crude methods. They cut long sluices and tunnels in the rock, either to carry water or remove the debris. For a similar purpose, broad, well-paved ditches were built, and at many places the condition of these sluices and ditches is still such that a good idea may be obtained of the general skill which was shown by the men who washed down those gigantic gravel deposits several centuries ago and filled the coffers of Spain with fabulous wealth.

The more modern, and especially American, methods of washing gold, consisting essentially of the long tom, riffle-box and cradle, are too well known to need another description. The Indian, wooden batea has been improved to the sheet-iron California gold pan, and, finally, on a smaller scale, by the vanning plaque, though the latter finds a more prominent use in the testing of concentrating ores.

The greatest improvement in modern gold washing has been made by the invention of the "giant" nozzle, so extensively used in California, which enables the miner to profitably wash gravel containing not more than six cents per cubic yard. This method of operation has thus far found but a very limited introduction in South America, where the ancient methods, above noted, are still in prominent use, the "Playa de Oro" mine in Ecuador being a prominent exception. In this mine the most approved modern methods are in use. There is no doubt that

WASHING A GRAVEL BANK WITH "GIANT" NOZZLES.

many millions still remain in those mountains to reward the enterprising man who is willing to provide an adequate water supply to extract them.

In Peru the placer mines are generally located on the eastern foothills of the Andes mountains, most prominently in the provinces of Sandia and Caravaya, located northeast of Lake Titicaca. Some of the smaller placers are found in the mountains, but almost always on the eastern watershed. The original extent of the placers in the foothills must have been enormous, though in many portions they have been washed away by the old Spaniards, 200 or 300 years ago.

At present, the remains of these mountains still reach a height of from 100 to 400 and 500 feet. The summits are sharp ridges, giving scant foothold, with precipitous gorges on either side. But in other places more compact deposits have been left, owing, either to their having been considered too poor to work at that time, or to the difficulty of providing a water supply. These deposits contain from 10 to 20 cents per cubic yard and in some instances even more was noted, sometimes reaching a dollar or more in favourable locations.

All of the hills are covered with a very luxuriant growth of tropical vegetation which would have to be removed before any mining operations can be commenced. In most cases the facilities for disposing of the debris are excellent. The principal difficulty to be overcome is the water supply which is mainly down in the valleys, though in some instances small stagnant lakes or little water rills are found near the summit. These, of course, are swelled considerably during the rainy season which lasts about five months each year.

The deposits are not in one continuous stratum, but in sections, scattered over a large tract of territory, though each deposit in itself must have been of great extent originally. The principal river of this region is the Pacchani, from 100 to 200 feet wide, which is fed from numerous smaller tributaries, entering it mainly from its west side.

In the tropical regions the deposits are now mainly worked by the natives intermittently in a small way, there being but few locations where work is being done throughout the entire year.

In these latter cases a more energetic miner has located, and systematic, though crude, methods are being pursued.

In one of the locations of Sandia, near the village of Poto, at an altitude of about 16,000 feet above sea level, there is a large gravel bank which has a fair water supply from a small lake that is fed by the snow from the mountain, and also an artificial dam, built across the mouth of a good sized watershed. The workings have been provided with two small "giants," drawing water from a penstock located about 250 to 300 feet higher. The gravel is washed into deep, paved sluices by the "giants," and from time to time a small reservoir, perhaps 15 to 20 feet above the sluice, is opened and the debris is washed down to the dump. Frequently, the enriched gravel between the paving stones is removed and washed in the batea.

The climate in these regions is very severe and cold. All necessaries of life, building wood and mining tools must be brought from a distance by freight animals. Fuel for culinary and heating purposes consists of the dried dung of llamas and cattle, which, though not very inviting, serves its purpose excellently.

On the eastern slope, villages are located on the main roads, generally at an altitude between 7000 and 12,000 feet. The buildings are fairly constructed of stone and a crude mortar, and are provided with thatched roofs, the long straw which grows abundantly in this section being used for that purpose. The furniture, as a rule, is of the very simplest character. The climate is delightful, except that during the wet season travel is impeded considerably, and generally avoided if possible.

ANOTHER VIEW ALONG THE PLAYA DE ORO PIPE LINE.

Another great gold placer region is located at the foothills on the western slope of the Andes mountains in the province of Esmeraldas in the northwestern part of Ecuador, about 40 miles from the coast, and about one degree north of the equator. These deposits are reached by water from Panama by a small steamer which travels for one

day along the coast and through the passages between the numerous islands near the mouth of the Santiago river. Then passage is taken in canoes for the next two days up the Santiago river, which has numerous rapids, necessitating slow traveling.

These placer gold fields, though known to the old Peruvians and subsequently to the Spaniards, were very little known to the present generation, except during the past few years when attention was again turned to them. The extent of the deposits is very great, and, with a number of small interruptions, are scattered over an area exceeding 100 square miles and possibly reaching 200 square miles. The banks of the auriferous gravel vary from 10 to 100 feet in height, and are claimed to assay as high as 20 cents per cubic yard in many places, while in exceptional positions several dollars have been produced per cubic yard, especially where the bedrock was favourable.

The region is traversed by several small streams and their tributaries, which, if intersected and led into a suitable reservoir at a higher level, may serve as a supply for washing the gravel. An abundant source of water supply is located at a distance of several miles from the deposits, but it will require considerable engineering skill and expenditure of money before this can be made available. Some of the small streams, where favourably located, may be used for removing the debris either entirely or partially.

The total rainfall in this region is very great, exceeding perhaps an average of half an inch for each day in the year. During the wet season, when all the rivers and brooks carry a larger quantity than usual, the general conditions for working the places are, of course, more favourable than when the water supply is lower.

These gravel deposits are owned by six companies, the members of which are mainly Americans,—a fact that would indicate ample enterprise for future developments, to continue the work which has been done during the past five years, when about $1,000,000 were expended for prospecting and developing. The most prominent company is the "Playa de Oro," which spent about $600,000 on its plant and great pipe line. The latter can carry about five times the amount of water which it receives at present, thus saving the expense of reconstruction or addition when a greater source of supply becomes available. This company has already obtained about 900 ounces of gold, resulting from its preliminary work and the opening up of the mines.

The "Cachavi," Uimbi," and "The Ecuador Gold Mining Co.," are also expending money on their respective properties for the purpose of surveying, prospecting and installation of plants, and therefore have not yet received any returns. Their course will shortly be followed by the "Lower Angostura" and "Esmeraldas Gold Mining Company," who have not yet begun operations.

Tropical forests cover a part of these places, and will have to be removed, but as the woods are partly valuable in the arts they may possibly be disposed of at no small profit, while the other wood could be used in the construction and improvement of the plant.

Like many of the great California deposits, these placers probably were the bed of a great river and there appear to be two distinct beds or benches, the upper of which was the older, the lower one having been formed by the subsequent deepening of the river. The Andes mountains were then uplifted and the waters, flowing to the sea in a new channel, intersected the old river beds, forming great cañons and leaving the sides exposed. At many places this peculiarity makes it a comparatively easy matter to prospect these vast deposits. In some cases the cañons are 300 feet in depth, and the small streams forming them enter into the Santiago river which is from 400 to 500 feet wide and from 20 to 30 feet deep, with numerous rapids and, therefore, able to carry off a large quantity of debris or washed gravel.

In many places along the banks small cuts or prospect holes were made by the

Indians and negroes, who washed gold in a small way. These cuts are readily utilised by the more intelligent prospector to determine the value of the deposit. Occasionally the miners find gold implements, such as fishhooks, nails, images and ornaments which would prove that these deposits were known to the old Inca race and were worked by them. About one hundred ancient tunnels driven close to bedrock have also been discovered which still further confirm this view.

While engineers and expert miners in these regions are Americans, the common labour is performed by the native Indians, descendants of original inhabitants of the land, though considerably mixed with white and negro blood. They are a very peaceable, though not very industrious, race. Both characteristics may be attributed to the climate, few necessities and comparative ease with which a livelihood is gained. These Indians dwell in villages located in the temperate mountain regions, and are always glad to find occupation in the mines when not employed on their own little farms. Their wages average about 60 cents per day. In order to induce foreign capital and intellect to develop the mines in Ecuador, that country has passed laws exempting mining property and products from taxation for a period of twenty-five years and in case an attempt should be made to alter these laws to the disadvantage of American citizens the United States would, of course, protect the property and lives of its citizens in the manner usually adopted in South American countries. The government of Ecuador has shown itself very friendly to these mining enterprises. It is building a telegraph line at the mines, and is willing to make a port of entry at the mouth of the Santiago river to facilitate shipments.

From all this it will be seen that the day is probably not far distant, when a part of the prodigious wealth which still remains in these South American mountains will be brought forth to reward the energetic engineer and enterprising capitalist who will replace antiquated mining methods by the highest grades of skill and perfection which modern science can supply.

FRANCIS HENRY RICHARDS.

ONE of the most interesting classes of men of the present time is the professional inventor, and of this class Francis Henry Richards, of whom an excellent portrait is given in this number, is an admirable representative.

Descended from a race of American farmer-mechanics, he exemplifies in a marked degree that self-reliant spirit of the early American pioneers, who never hesitated to attempt what needed to be done. What better training-school ever existed than the old-time New England homestead, with its ample fields and buildings and "shop," where the husbandman and his boys worked the farm together in the summer, and in the winter carried on the manufacture of all that the farm and home required? Carpenter, blacksmith, shoemaker, millwright, weaver, all in one, those farmer-mechanics were most worthy progenitors of the modern engineer, who, with the accumulated facilities of centuries of freedom, is so rapidly remoulding the life and destiny of the race.

Mr. Richards' inventive genius was, in a large part, inherited from his ancestors, who taught and practised the theory that a farmer should always be able to make his own tools. At the early age of fifteen he began building machinery of his own invention, and has been actively engaged in the development of mechanical industries since that time. Beginning his career in the

factories of the Stanley Rule and Level Company, at New Britain, Conn., under the tutorship of his father, Mr. Henry Richards, an ingenious mechanic and inventor, by systematic study and application extending over a period of eight years, he acquired a practical and theoretical knowledge of the machine-building trades, including woodworking, forging, and the allied branches. Mr. Richards has made many and frequent tours for the critical observation of machinery and manufactures, made a thorough study of patent law, and brought out numerous inventions of labour-saving machines, the majority of which, with his added improvements, are now in successful operation.

The indexes of the U. S. Patent Office show that, up to the present writing, 343 patents on his own inventions have been issued to him, thus ranking him third in the list of American patentees. In addition to these, he has invented a great many valuable machines and devices for which he never applied for a patent. Among his invention may be mentioned an envelope machine, which prints, folds, gums, counts and bands, automatically, 80,000 letter envelopes per day, greatly exceeding any other machine in its capacity and in its economy in the consumption of paper.

Among his more noteworthy recent inventions is a new automatic weighing machine, which is rapidly coming into general use for a wide range of purposes. This machine is of the single-bucket class, very sensitive in action and rapid in operation. An important feature is the system of interlocking safety-stops, modeled upon the well-known block signal system, by which the operation of the valve and bucket mechanisms is made positive and reliable under all conditions, thereby attaining an object not previously reached in this class of weighing machinery. This machine is used for weighing and registering all kinds of granular materials.

Mr. Richards, also, in 1873, invented and patented the fundamental features of the air-cushion door-springs that have since come into such general use. He has been among the foremost in developing manufacturing enterprises based upon patents, and, during his connection with manufacturing, has worked in all capacities, from apprentice to supervising engineer and proprietor.

In his business career he ranks among the ablest, and is recognised as one of the most reliable mechanical engineers of the day. He has been unusually successful in his business, which consists in developing and patenting mechanical improvements and inventions, and he is consulting engineer and adviser for several of the most prominent manufacturers of the United States. In recent years, especially during the last decade, there have developed from the ranks of inventors, and chiefly from those engaged in engineering work, a few recognised leaders, who have reduced to a science, so to speak, the making of inventions, and it is to this class, by reason of his many years of work in this special field, as well as the successful results of that work, that Mr. Richards properly belongs—the professional mechanical inventor, whose genius and training are placed at the disposal of the manufacturer who needs an invention, and of the inventor who requires expert counsel and assistance.

The systematic control of the powers of nature—a control which can be obtained only by the systematic methods of the trained engineer, aided by the native ingenuity of the inventor—is adding to the wealth of the world in a proportion which, ever increasing, already exceeds all other sources combined. In the prosecution of his business, Mr. Richards conducts, at Hartford, Conn., extensive engineering and patent offices, employing a large corps of assistants, and equipped with ample facilities for this peculiar line of work. As a solicitor of patents and expert in patent cases, he has made it his successful aim to attain the highest position.

Mr. Richards has been a member of the American Society of Mechanical Engineers since its organisation in

1881. He is also a member of the Civil Engineers' Club of Cleveland, O., the Engineers' Club of New York city, and of the American Association of Inventors and Manufacturers. Personally, Mr. Richards is one of the most unassuming of men, but has a cordiality to those with whom he is associated that ranks him as a man of strong character.

Current Topics.

One very excellent reason why government contracts in England, at least those pertaining to naval construction, are not popular with, nor specially sought after by, some of the foremost engineering firms of that country, has been furnished by the experience which Messrs. Yarrow & Co., the well-known torpedo-boat builders, have more recently gone through with the British Admiralty, and which is about as unique as it is condemnable. Messrs. Yarrow & Co., as is pretty generally known, were the first, several years ago, to turn out vessels of the torpedo-boat destroyer type. The success attained by these was remarkable at the time, and more recently, therefore, it was determined by the Admiralty to order a large number of them, of the latest and still further improved design, and to extend the orders for them to builders of larger vessels in the northern shipbuilding districts, who, it is admitted, did not then have much experience with craft of this kind. Instead, however, of inviting these newer firms to submit designs of their own, the Admiralty, with, no doubt, laudable intentions so far as the good of the department and of the country was concerned, but with entirely unwarrantable freedom with someone else's property, proceeded to have Messrs. Yarrow's drawings—which had been confidentially submitted—traced and distributed among these other establishments.

It is not to be wondered at that Messrs. Yarrow have most emphatically protested against this strange proceeding, which may well put other builders of original machinery on their guard when dealing with the government. Had the latter acquired property rights in the drawings, there might have been no question as to its privilege to make any use of them that it thought proper. As it is, however, the Admiralty used documents confidingly submitted to

them as though they were their own. Certainly, no argument seems necessary in this case to convict them of having been guilty of a practice which every right-thinking contractor will condemn, even though he may have profited by it. What the Admiralty has done in this instance appears to be but a sample of other similar methods followed by it for years, less seriously aggravating, perhaps, but none the less unworthy of a great government. The result is already apparent by the preference which is shown by some of the prominent English contractors for the work of other governments, and this preference may be expected to increase largely if the universal distribution system of one contractor's drawings among his competitors is to be followed in future.

THE present revival of interest in the metric system recalls the one point in that system which, so far as yet appears, has failed to meet the requirements of machine shop practice, *i. e.*, its non-adaptability to a convenient system of screw threads. Numerous attempts to devise metrical screw thread systems have been made, but no one of these has thus far met with sufficient approval to secure general adoption. It has well been remarked that it is very much easier to adopt a new system than it is to throw away an old one, and hence each attempt to improve the metrical screw thread systems has simply resulted in the addition of one more to the existing list, without superseding any of the preceding ones. Thus, there are in France the systems of the French navy, of the Chemin de Fer du Nord, of the Paris–Lyons–Mediterranée Railroad, and those of Armengaud and of Cail. In Switzerland there are the systems of Reishauer and Bluntschli, and of Bodmer; in Alsace-Lorraine, the two systems of Ducommun and that of the Engineering Society of Mulhouse; while in Germany there is the system of the Pfalz-Saarbruck Society, that of Redtenbacher and the two systems of Delisle, the latter one of which has also been adopted by the Society of German Engineers. There are, thus, no fewer than fourteen different metrical screw thread systems, no two of which will interchange. The difficulty appears to consist in the fact that the decimal subdivisions or multiples of the millimeter do not give sizes which conform to the mechanical requirements of strength, wearing capacity, and convenience of angle, while the introduction of other than decimal fractions at once takes any system out of the pale of metric orthodoxy.

A FEW months ago the writer paid a visit to the great steam engine works of Gebrueder Sulzer, at Winterthur, in Switzerland, and knowing that this establishment ranked as one of the very finest machine shops on the European Continent, he had the curiosity to inquire as to the system there used. He found, to his surprise, that the English Whitworth system was used exclusively for all bolts, nuts and screw threads, the dimensions being made in inches and parts thereof, and Whitworth's gauges were used. This, of course, is the case only with screw threads, all other dimensions of the engines being taken in the metric system. Mr. Carl Sulzer, from whom this information was obtained, said that in the present confused state of the metric screw thread systems they considered it inadvisable to adopt any of them. The choice of the Whitworth rather than the American system was not due to any especial preference for the former over the latter, but only to the greater convenience of procuring taps, dies and gauges from England rather than from America.

REFERRING to the high reputation of Messrs. Sulzer, and the opinion expressed by several foreign engineers of high repute as to their standing as one of the best equipped firms in Europe, it was most interesting to observe, in the course of a careful tour of inspection, that a large proportion of the

tools used were of American make. Lathes, shapers, milling and grinding machines, everywhere bore the familiar names of representative American firms; and even when the names were foreign, the designs were American. This is not surprising when we know that one of the younger members of the firm passed several years in the leading American shops, and that in the library of the handsomely equipped offices the shelves are filled with neatly bound files of the principal American technical journals. The products of the works and their notable performances are too well known to need comment here. It is sufficient to say that a critical inspection of work in progress showed such admirable castings, careful fitting, and painstaking supervision, as to warrant most fully the right of this great establishment to its reputation as one of the leading machine shops on the Continent.

One of the several interesting features of the steam boat *The New Yorker* which, with others, is illustrated in the article on "Fire-Boats" elsewhere in this issue, is to be found in what is known as the Kunstadter steering screw, first brought into prominence about twelve years ago at which time it was tried with quite satisfactory results on a number of vessels, both in the United States and in Europe. Since then, however, comparatively little has been heard of the device, notwithstanding its admitted excellencies in some respects. While the sectional view of *The New Yorker*, on page 40, will help to give a fairly good idea of the nature of the arrangement, it has been thought well to present a still clearer view in the little sketch above. It will be noticed that the steering screw, or after screw, shaft is carried through the rudder and is connected with the main propeller shaft by a universal joint, so that it may be turned with the rudder, either to port or starboard, up to an angle of 45 degrees and thus add its influence to that of the rudder in turning the vessel. One immediate result is that the rudder may be made much smaller than would ordinarily be the case without detracting from the manœuvring capacity of the vessel, and with the usual proportions of rudder and screw, relatively to size of hull, the steering screw would cause a vessel, so it has been claimed, to make a complete circle, for example, in half the diameter required with the rudder alone. Despite this manœuvring superiority, however, the Kunstadter apparatus does not seem to have gained much favour in the past dozen years, due probably to the fact that it may not lend itself satisfactorily to use on large vessels because of constructive difficulties, and because also on small craft its advantages are not so marked, comparatively speaking, nor of such great importance as to make it particularly worth having, except in special cases.

THE KUNSTADTER STEERING SCREW.

The advantages and disadvantages arising from the substitution of ribbed glass for plain glass in factory windows were recently investigated for the Bos-

ton Manufacturers' Mutual Fire Insurance Company, by Mr. Charles L. Norton, of the Massachusetts Institute of Technology, and the results have been published in one of the company's characteristic circulars. Mr. Norton, to begin with, points out that, in both fair and cloudy weather, the general resultant direction of light entering through a window having ordinary glass is downward at an angle of about 40 or 50 degrees. The brightest portion of the room is, therefore, the floor in front of the window. As a floor is not, as a rule, a good reflecting surface, a large amount of light is absorbed there and lost. Whatever light is reflected goes upward and backward toward the ceiling, and what light falls on the wall spaces between the windows must, therefore, be mainly light which is diffusely reflected from the floor and objects upon it. Early in the morning and toward evening the angle of the incident light with the horizontal is less, and the light, therefore, penetrates further into the room, but the wall spaces between windows gain but little by this greater obliquity. If panes of ribbed glass be substituted for the plain glass, the bright spot on the floor in front of the window disappears, and the entire floor, walls and ceiling appear of sensibly the same brilliancy. The action of the ribbed glass appears to be prismatic, the greater part of the light falling on the ribbed glass at any point being refracted and spread out into a fan-shaped beam lying in a plane nearly perpendicular to the plane of the glass and to the direction of the ribs. This being recognised as the probable action, photometric measurements of the intensity were made at a distance of eight feet back of the glass in a horizontal plane, at five angles in this plane.

Two panes of glass whose relative merits were to be compared were set, one above the other, in a large window having a southerly exposure. On the inside, with the panes for centres, were built two rooms, semicircular in plan, and each about three feet high and eight feet radius. Outside the rooms was a photometer room entirely enclosing both. The panes were 18 inches square. At corresponding points in the two rooms holes were cut in the side walls, and disks of semi-transparent membrane, ground glass or paper were placed over the holes. One hole was directly opposite the pane, and the others were at 30 and 60 degrees to the right and left. The holes in the lower room were directly under those in the upper room, and by means of a system of mirrors any two corresponding disks could be viewed side by side. If one disk was brighter than the other, the corresponding pane was obscured by a shutter sliding across it until the disks appeared equally bright. The amount of light falling upon the two disks now being the same, the amount transmitted per unit of area of the glass is inversely as the area exposed.

It must be distinctly understood that this does not give the amount of light actually passing through the glass, but simply the amount which passes through in such a manner as to be available at the disks. Thus, if half of the ribbed glass pane has to be obscured in order to equally illuminate two corresponding disks, the ribbed glass is transmitting to the disk twice as much light per square inch as is the plain glass, and, hence, of two equal windows, the ribbed glass window would give to objects situated in the general direction now occupied by the disk twice as much light as the plain glass window. It was found that the effect of having the ribs horizontal was to give an increase of light at the middle hole, and a less increase at the sides, whereas the vertical ribs gave a greater increase at the sides and a less increase at the middle. The horizontal ribs tend to throw the light which would otherwise fall to the floor straight ahead far into the room, while the vertical ribs spread out the light on both sides. It is, however, useless to discuss the measurements of

the distribution with horizontal ribs, as the brilliancy of the glass itself is then so great as to be unbearable, rendering its use in this position out of the question, for most purposes. The diffusion of heat was much the same as the diffusion of light. There was no spot where the heat rays from outside streamed directly in when ribbed glass was used, and objects near the window were cooler than when plain glass was used, by from 4 to 15 degrees Fahrenheit. However, the ribbed glass itself is hotter than the plain glass, and the temperature of the air in the two cases was not sensibly different.

THE windows of several large factories have thus far been fitted up with ribbed glass, and the effect in each case has proved startling, each room giving the impression of almost unimpaired daylight. No window-shades are required, and the results have proved wholly satisfactory. In two instances. rooms in factories which are overshadowed by neighbouring buildings are now being fitted with this glass, and it has been remarked that the relative increase in the effectivenes of light is much greater where the light is derived indirectly than where it is derived directly from the sun to which the windows are exposed. It has been suggested that manufacturers might test this matter at very small expense, selecting one or more windows in especially dark places for the purpose of observing the effect. A very large new establishment near Boston is now being glazed in this way. The effect is already manifest from a partial application of the theory. The working men and women in this establishment are of a very high type; hence, the foreman reasoned that objection might be taken to the complete closing of the outlook from the factory by the use of this glass throughout the window. The windows in this factory are of the ordinary lifting type; therefore, the lower panes have been glazed with plain or clear glass, while all the rest of the window is glazed with the ribbed glass. The effect of this is said to be entirely satisfactory and very pleasant.

IT is most interesting to compare the different methods by means of which the highest grade of mechanical perfection is attained in various countries. Notwithstanding the high character of American watches, for example, the finest Swiss watches still maintain their great reputation. The Swiss workman receives the parts from the manufacturer in the rough, takes them to his home, puts his best individual skill into the finishing and assembling, and brings the completed watches to his employer. The latter inspects the work and out of a batch of, say, fifty watches he selects five or six as worthy of his own attention, and puts the others into the regular trade under some general trade name. The selected watches he readjusts, working over them for days, weeks and months before he considers them worthy to bear his own name, and it is these watches which go to those who not only have the money to buy, but also the patience to wait.

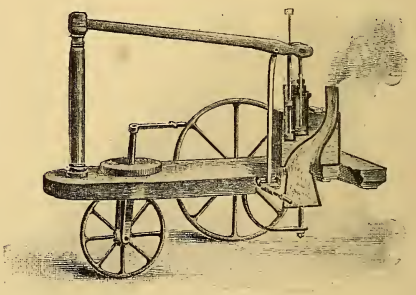
A PROMINENT firm of American jewelers, chafing under the inconveniences of this old-world method of doing things, sought to introduce American methods and see if the highest grade of Swiss watches could not be made more methodically. A factory was built, enticing rates of wages were offered to the most skillful workman, and the experiment was tried. But, alas! The Swiss workman soon found that no regular wages could pay him for his loss of liberty. To be on hand when the whistle blew in the morning, to have his stated hour for dinner and his fixed hour for quitting at night—these restrictions he could not long stand. Formerly he had worked when he felt like it and stopped when it pleased him, and when he was paid for one job he took his own time to begin

the next, generally waiting until his funds ran low. The factory plan did not work for long, and the idle building now bears silent testimony to the Swiss love for independence which is as much a factor in present life as it has been in past history.

THE fact that much of the work of the Swiss watchmakers and instrument makers is done in this primitive manner does not in the least detract from its high quality, but rather adds to its perfection by embodying in each article the individual skill of the workman. The writer desired to procure one of the famous Goldschmidt aneroid barometers, and only after some difficulty and many inquiries did he succeed in finding the whereabouts of the maker at all. At last he was directed to the quaint street in the old quarter of the city of Zurich known as the "Trittligasse" (the street of the little steps). There he found a gate in a wall bearing the desired number, but no name or sign of any description to indicate what was within. Knocking to obtain admission, he was finally let into a garden, over another wall and up a picturesque set of steps, and ushered into a little room in which was work of the finest description. A few men and boys, a couple of women—this was the working force; but here were products which surpassed the finest instruments of any he had ever seen—instruments that would have been a credit to vastly more pretentious establishments. Each article was shown and handled as if it had been a personal pet, hardly to be parted with; and it was, indeed, interesting to see how every instrument was calibrated and tested and recorded in a manner which could not but prove that for such work individualism had its advantages over collectivism. The articles were indeed "manufactured" in the true etymological sense of the term, "hand made," and head-made, too, for that matter; and all this in a little out-building accessible only after diligent search and many misadventures.

IT may be of interest to note that, the United States navy authorities have decided to fit the Babcock & Wilcox boiler to some gunboats recently ordered, and that this decision was come to after careful trials in the *Zenith City*, one of the American lake steamers. The boilers in that vessel are 106 lb. weight per indicated horse-power, and 25.57 lb. per square foot of heating surface. The grate surface on trial was 67 square feet, the heating surface 2800 square feet, and 600 square feet in heater. On a 24 hours' run the power developed was 1540 indicated horse-power at 87.5 revolutions, the steam pressure being 190.75 lb. per square inch. The coal burned per square foot of grate was 25.94 lb., the evaporation per pound of coal 7.05 lb. and the consumption per indicated horse-power 2.256 lb., although in other trials it was a trifle lower. The moisture in the steam averaged about three-tenths of 1 per cent. In a ship exactly similar, but with multitubular boilers, the weight per indicated horse-power is 175.8 lbs., and 58.7 lbs. per sq. ft. of heating surface; but the trials in this case were interrupted by a break-down of the water-meter.

IT is interesting at this active time of horseless carriage building to keep



MURDOCH'S ROAD LOCOMOTIVE, 1784.

in view the accomplishments of earlier years in the same line. No other plea

is necessary for the appearance on this page of Murdoch's early road locomotive, mentioned, too, in the article on horseles carriages in the April number of this magazine, and with which experiments were made as long ago as 1784. Murdoch first tried the little engine in his own house, but, later on, tested it out of doors, when, small as it was, it fairly outran the speed of the inventor. Dr. Smiles, in his "Lives of the Engineers," well describes the scene, telling how, one night after returning from his duties at the mine at which he was employed, Murdoch went out with his model locomotive to the avenue leading to the church, about a mile from the town of Redruth. The walk was narrow, straight and level. Having lighted the spirit-lamp which heated the boiler, steam was soon raised and off started the engine with the inventor after it. Shortly after, he heard distant shouts of terror, and when he came up to his machine he found the vicar, in great fear, thinking that the hissing, spitting little demon was no other than the Evil One himself. What the engine was like becomes clear from the little sketch itself.

ANOTHER contribution to the history of horseless carriages is given in an interesting little volume entitled "One and All," published by Messrs. S. W. Partridge & Co., of London, and which is an autobiography of Sir Richard Tangye, of the famous Cornwall Works, at Birmingham. Sir Richard tells in this that about 1862 the subject of providing "feeders" in country places for the main lines of railway came again into prominence. Branch lines had been proved to be unremunerative, from their great cost of construction, and among other systems proposed was that of light, high-speed locomotives for carrying passengers, and traction engines for the conveyance of heavy produce and other goods. The Tangye brothers, therefore, determined to build a locomotive of the former class, and succeeded in making a very successful example, with which they trav-

TANGYE'S ROAD LOCOMOTIVE "CORNUBIA," 1862.

eled many hundreds of miles. The firebox was made of copper, and there were nearly 100 metal tubes in the boiler, enabling them to get up steam very quickly. The total weight of the locomotive was 27 cwt. The machinery was simple and compact, and the whole outfit occupied no more space than an ordinary phaeton. It was capable of carrying ten persons. The greatest speed obtained was over twenty miles an hour, and the engine was easily managed and under perfect control.

GREAT interest was manifested at the time in the Tangye experiment, and it soon became evident that there was an opening for a considerable business in these engines, but the "wisdom" of Parliament made it impossible. The squires became alarmed lest their horses should take fright, and an act was passed, therefore, providing that no locomotive should travel at more than four miles an hour on the

public roads, and that they should all be preceded by a man carrying a red flag. Thus was the trade in quick-speed road locomotives strangled in its cradle, while, without doubt, more horses have been frightened by the red flag than would have been by the locomotives.

Now that so many are working on petroleum motors for road carriage use, a few hints regarding the proper manner of making petroleum joints that will not leak ought to be acceptable. Every one who has had any experience in this line is familiar with the annoying persistency with which petroleum will come through almost every imaginable kind of joint, so that many have supposed it to be quite impossible to make one that would not leak, especially with the light varieties, such as naphtha and gasoline when subjected to both heat and pressure. Mr. Maxim, the well known inventor, however, recently said in *The Engineer*, of London, that it is no more difficult to make a petroleum-proof joint than it is to make one that will be water proof. To use his own words, "in making up steam or water joints we naturally employ something which is insoluble in water. If an ordinary steam or gas fitter is asked to make a petroleum-tight connection, he is almost sure to employ red lead and oil, and for a gasket or washer, he is equally sure to use india-rubber, both oil and india-rubber being quite soluble in petroleum. In my experience I find that a joint which is screwed together dry is less apt to leak petroleum than a joint made up of the orthodox red lead and oil.

"To make a good petroleum joint with common iron pipes, a very good system is to heat both the male and female threads sufficiently to dissipate every trace of oil. Then make the joint up with thick shellac varnish, which may be combined with ordinary dry vermilion or even Venetian red. A joint of this kind I have found to stand well. A very good joint can also be made with ordinary yellow bar soap rubbed into the threads of the pipe, the grease first being removed. Treacle, honey, glue, mucilage, or glycerine are quite petroleum-proof. For a stuffing-box, ordinary wicking saturated with common yellow bar soap may be safely employed. Canvas, saturated with shellac varnish, makes a good washer, but soft metallic washers are better. A very good flexible diaphragm for a regulator may be made of closely-woven cotton fabric, varnished on both sides with a compound of gelatine and glycerine. About equal parts by weight make a very tough and elastic compound. Wooden vessels, bags, etc., may also be made petroleum-tight by saturating or varnishing with this compound. As a rule, all substances which are soluble in water are quite insoluble in petroleum. For stuffing-boxes for standing both water and petroleum, castor oil may be employed, as this peculiar oil seems quite insoluble in either."

WRITING of "The Eight-Hour Day" in a recent number of *Dixie*, J. H. Allen cites a unique case in the United States where there was an actual strike against the reduction in number of working hours, though no reduction of pay was involved. "There was a saw mill in the pines of southern Georgia," says Mr. Allen, "where the hours of labour ran from dawn till dusk, where unions were unknown and the feet of the walking delegate had not trod. A Northern man was sent down as superintendent, to whom the ten-hour day, from seven to six, appeared to be about right, and he at once proceeded to establish this new order of things. All went well for the first two days, but at the end of the second he was waited upon by all hands, for whom the spokesman said:—'I reck'n you all jess doan know 'bout dis yer mill. 'Pears to us dar yaint no sense in gittin up at fo' or five o'clock

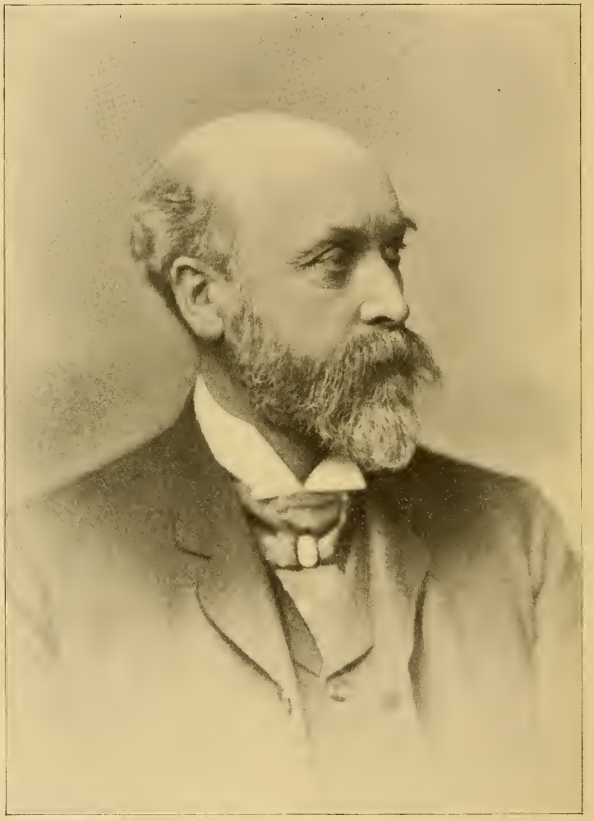
in de mawnin and set'n 'roun till seben befo' we goes to wuk. An den in de ebenin' it jess de same way. Now we all jess ain gwine ter stan' it, dat's all.' So the old order was resumed, and the men worked from dawn till dusk, and the Northern superintendent rose by the light of the stars in every season." The story very aptly illustrates the fact that where there is nothing to occupy the mind during hours of leisure the shortening of the day of labour does not always come as a blessing. It is this, too, which helps to explain why country labourers, as a class, will contentedly plod through a day whose length would be appalling to all but a few city workers.

Apropos of excessive stokehold temperatures aboard ships—a subject much discussed in the last few years—it is interesting to note some of the points mentioned in a recent official report of the Surgeon-General of the United States Navy. Concerning the cruiser *Cincinnati*, for example, he says:—"Temperatures are recorded from 90 deg. to 170 deg. Fah. Tentative efforts made in November to improve the system, particularly the blowers in fire rooms, have not succeeded in ameliorating the heat now common in those places. I have myself recorded fire-room temperatures as high as 168 deg. Fah. In the engine-room lower platform the average is about 102 deg.; on the upper platform it frequently reaches 135 deg. By the present system of forced ventilation for the engine department very little air above the rail is taken. Air is mainly taken through the spar-deck hatches; also in part from the after-berth deck, and from beneath the deck near the large engine-room hatch. Blowers in the condenser room force air to the engine room proper, and those above the upper platform of the engine room pass the air to the fire rooms. When under way, a wind sail sends an additional supply of fresh outside air to the condenser room. The supply gotten above the upper platform in the engine room, in addition to its warmth, is also somewhat contaminated by contact with metal and oily surfaces. The blowers in the forward fire rooms do not properly function at present, and are said to be useless. Their supply is through broad louvres under the pilot house. The six fire-room ventilators extending well above deck houses are 20 inches in diameter, and it is through them the fire rooms get their main supply of fresh air. The condenser-room blowers ventilate the main engine room. Unless these excessive heat conditions in the fire rooms, contiguous passages, and intricate coal bunkers are remedied, it cannot be expected that the men will long endure continuous labour there. It is physically impossible for the class of men enlisted for this purpose in our navy to undergo the strain of these unfortunate conditions. Though the ship has had as yet no severe or continuous steaming, the firemen constantly apply for relief from symptoms of heat irritation, such as muscular cramps, disordered heart action, nausea, head pains, and weakness." No engineer at all familiar with the conditions aboard a modern high-class steam vessel will question the entire correctness of these statements. They apply, however, not only to the ships of the United States Navy, but to those of other countries as well, and also to many steamers of the merchant marine. All these vessels afford good examples for treatment with modern approved methods of ventilation, which ought to accomplish much in the way of improved working conditions.

Pure, fresh air, of uniform temperature, makes the operating room of the Chicago Telephone Company about the most desirable place in which to work in Chicago. Down in the basement of the building is a big rotary fan that sucks in the air which the ordinary citizen is obliged to breathe. As the current enters the basement, through a huge tube, it passes into a tightly closed

chamber in which an artificial rainstorm is constantly raging. This is effected by three rows of small nozzles, or atomisers, which discharge a cloud of spray and remove every particle of dirt from the air. The dirt passes off into a well, while the air is whirled through a battery of spiral tubes. The twisting motion removes excessive moisture from the air, and it then passes into another chamber, where it is heated in the winter or cooled with ice in the summer. Then the current is directed upward through a shaft that leads to the top floor of the building and into the operating room. Every window in this is tightly closed and sealed around the edges, while double doors make it necessary for one to enter the room through what constitutes an air-locked passage. The supply is forced through vents opening through the ceiling from a duct that runs around the room. It is really compressed air, although its density is so slight as to be almost inappreciable. Every three minutes the air is completely changed, the supply being calculated at 10,000 cubic feet a minute. It leaves the room through outlets fixed in each window, that are provided with delicately adjusted valves opening outward. These outlet tubes take in the air from near the floor, the current being strong enough to draw a piece of paper through the tube and throw it outside. As the valves open outward, there is no chance for the introduction of foul air from the street. A self-recording thermometer in the operating room tells the story of the success of the system in unmistakable language.

SPEAKING recently of the needs of a great technical college, and incidentally of the fact that very few laymen have a knowledge or even a conception of the magnitude of the work of educating a nation, Dr. Robert H. Thurston said that there are in the United States, for example, about 40,000,000 of children requiring instruction, 20,000,000 who have, or who will ask, secondary education, and at least 100,000 young men and women capable of and rightly demanding the opportunity of securing higher education. When we are told that the United States government has given to the cause of education 150,000,000 acres of public lands, and that Cornell University alone has sold over $5,000,000 worth of her endowment, and has still 5000 good farms left for sale, the States sometimes expend as much as $25 per capita of their population, and cities as much as $35 on their public schools, we get a better idea of the extent to which a people make sacrifices of wealth for the benefit of the rising generation. Above $100,000,000 are spent annually by the American commonwealth on education, maintaining 200,000 schools and their 300,000 teachers, two-thirds of whom, by the way, are women. Even greater sums, proportionately, are spent in some instances by European States. Prussia spent $4,000,000 on its great technical school at Charlottenburg. Zurich has spent about $500,000 on its great chemical and physical laboratories at its "Polytechnicum." Saxony pays out nearly $500,000 annually on its university. The endowments of Harvard University are between $6,000,000 and $8,000,000; those of Johns Hopkins are $4,000,000 or $5,000,000, and those of Cornell and Columbia fall between these enormous figures.



FROM A PHOTOGRAPH BY HENRY VAN DER WEYDE, LONDON.

LOCOMOTIVE SUPERINTENDENT OF THE LONDON & NORTHWESTERN RAILWAY.

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CASSIER'S MAGAZINE.

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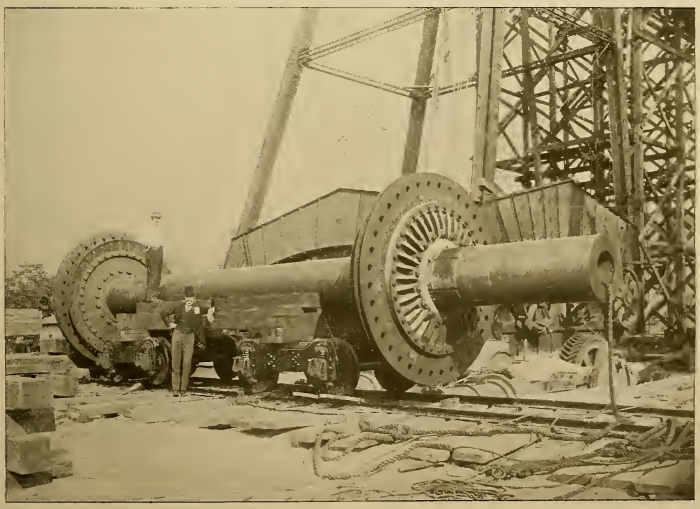
MAKING STEEL FORGINGS IN AMERICA.

By H. F. J. Porter.

IT is scarcely twenty years since the rolling mills of the United States, following European example, and after long experimenting and elaborate preparation, began to change the nature of their product from iron to steel; but short as this time is the change has been complete, and the latter material has supplanted the former to its absolute exclusion for rails, tires, etc., and, to a very great extent, for structural shapes, plates, bars, and similar material.

The beginning of this radical change began to open the eyes of manufacturers of machinery generally to the advantages to be obtained by the introduction into their product of a stronger material



THE FERRIS WHEEL SHAFT—OUTSIDE DIAMETER, 32 INCHES. INSIDE DIAMETER, 16 INCHES. LENGTH, 45 FEET. WEIGHT, 89,320 LBS.

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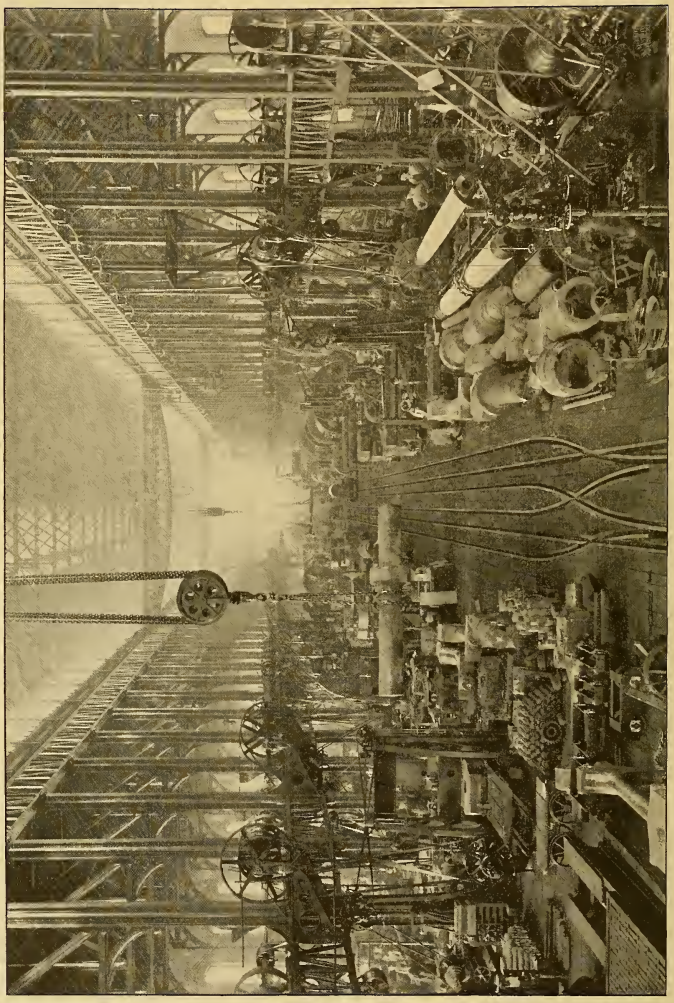


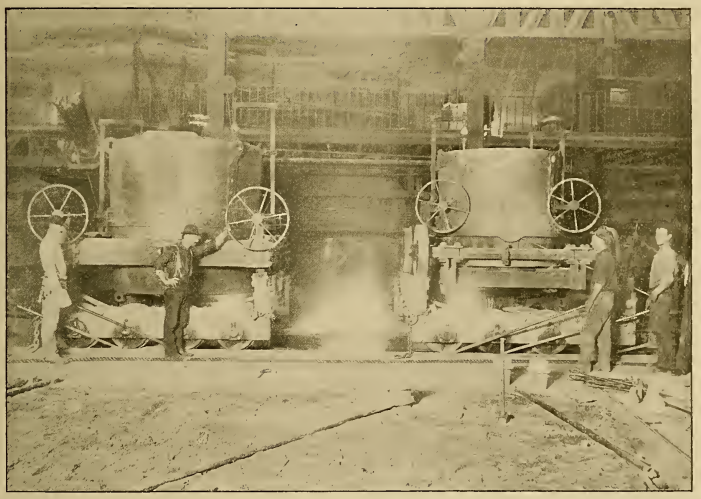
A VIEW OF MACHINE SHOP NO. 2 OF THE BETHLEHEM IRON CO.

than they had been using, and a demand arose from the trade for steel forgings of a high grade.

It did not follow, however, in the early stage of the development of its manufacture, that steel, as then made, was universally serviceable for use in the trades, and above all, that forges which had been accustomed to handle nothing but wrought iron, were at once prepared to furnish steel for general purposes. It must be understood that iron and steel are different materials and require widely divergent treatment in their production.

Such American manufacturers and engineers, therefore, as appreciated these facts and yet wanted to put into their product and structures the best material they could get, went to European forges for their supply and obtained what they required. Others, however, who were not so far-sighted, did not look further than to local forges for assistance, and these latter, without preparation and without previous experience in the handling of steel, attempted to supply their demands What they were able to produce, however, was, in many cases, not satisfactory, and after a few disastrous experiences, many manufacturers returned to wrought iron, satisfied "to leave," what they thought, "well enough, alone."

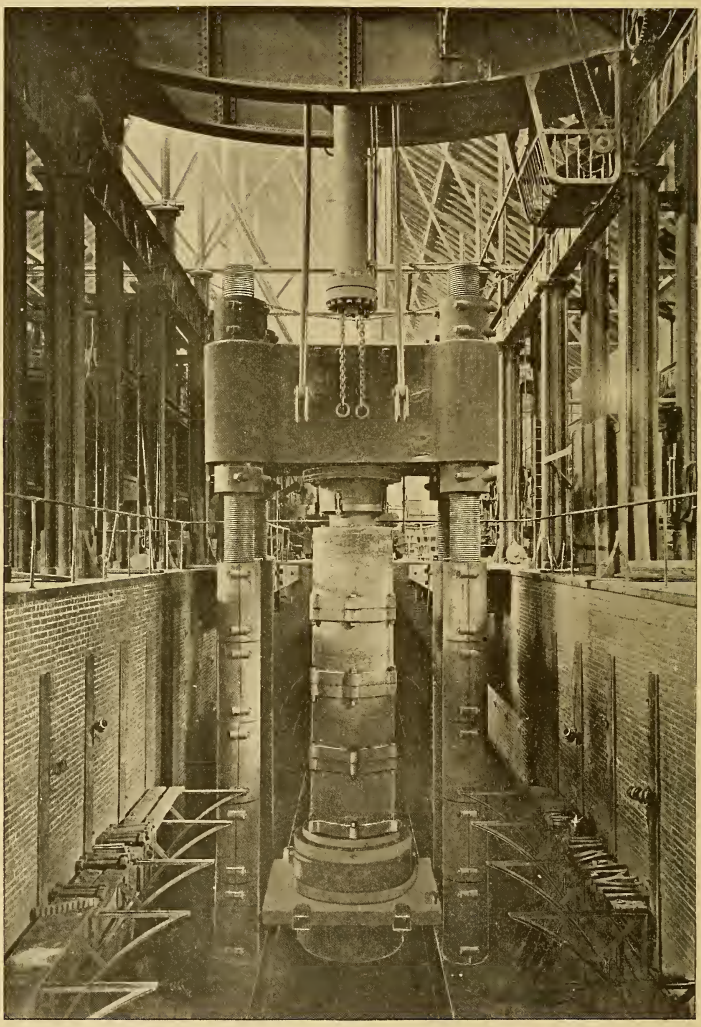
Thus, for a time, until the situation was understood, the impression gained ground among the uninformed that steel forgings were not to be relied upon.



CASTING AN 80-TON ARMOUR PLATE AT THE BETHLEHEM IRON COMPANY'S WORKS.

But of late, facilities have been offered in the United States to procure as good steel forgings as can be obtained in Europe, and representative manufacturers and engineers, influenced by their accustomed progressiveness, have rapidly taken advantage of them, and, if signs do not fail, it is a question of a short time only when steel will drive iron entirely from the domain over which it has so long held sway.

It was just ten years ago when, foreseeing the general demand that, undoubtedly, would shortly arise for steel forgings of a high grade, and appreciating how far the forges of the United States were behind those of Europe in the production of such material, the



END VIEW OF THE CASTING PIT AT BETHLEHEM, SHOWING THE FLUID COMPRESSION PLANT.

Bethlehem Iron Company decided to establish at their already well-known works at South Bethlehem, Pa., a forging plant, superior to any yet built, especially suited to turn out steel forgings only, and of a completeness and capacity to meet any demands that might be made upon it by any country, either for government or commercial work.

Determined to begin at the most advanced point then attained, they opened correspondence with Sir Joseph Whitworth & Co., Limited, of Manchester, England, and with Schneider & Co., of Le Creusot, France, both of which firms were acknowledged, at the time, to be foremost in the production of steel forgings for general and special purposes. This correspondence resulted in contracts whereby they were enabled to duplicate such parts of these plants as they would require, and were given full information as to manufacturing methods and shop practice. The money value of these contracts was very great and has rarely, if ever, been exceeded by that of single orders given out by a private concern. This fact, of itself, is the best proof that the management was satisfied that they were working in the right direction.

While availing themselves of the opportunity of obtaining this machinery, they did not neglect to improve its design where possible, and, in some instances, to enlarge its capacity considerably; and since that time they have not ceased to add such special appliances as improvements in practice have demanded, so that, at the present time, they have a forging plant superior to all others in existence.

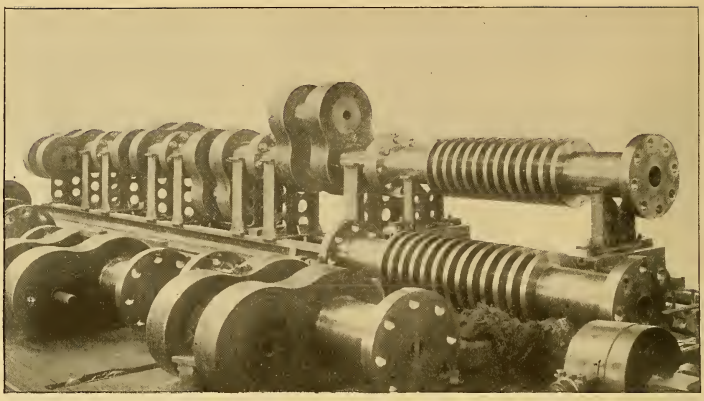
This plant has been described from time to time, more or less, in detail in the technical press, but it will not be amiss to mention here some of its most salient features. But, first, it will be well to premise that it is but an adjunct to an already complete rolling mill. The Bethlehem Iron Company owns its own mines, from which it procures its ore, has its own blast furnaces for reducing the ore to pig iron, and its Bessemer converter plant for changing the pig iron into steel, and has been making rails, billets, muck bar, etc., for the market for the past twenty-five years. In addition to this, it has now nearing completion an extensive mill of the most modern type for rolling plates of all descriptions. All of this is, however, entirely independent of the plant about to be described.

This plant consists of the open-hearth furnace and forging press building, 1115 feet long by 111 feet wide, with annexes for gas producers, engines, pumps, etc., on either side. On an elevated platform, to which the various ingredients of the charges to be melted are raised by hydraulic lifts, stand four open-hearth furnaces of 10 and 20, and two of 40 tons capacity, respectively, and to these are being added four more of 40 tons capacity, which will, when finished, increase the total melting capacity at any one time to 270 tons. These furnaces empty their contents into ladles carried on trucks, which, in turn, transfer it to moulds conveniently located underneath them in a pit. These moulds can be conveyed to a 7000 ton hydraulic press for compressing the liquid metal in them.

In this same building are two forging presses, one of 2000 tons and the other of 5000 tons capacity, and in the smith shop adjoining are steam hammers for light work. Close by are annealing ovens for treating forgings after leaving the forge shop.

Parallel with this building is machine shop No. 2,—1246 feet long (¼ mile, lacking 74 feet) by 111 feet wide. This shop is supplied with power by four 200 horse-power engines, two on each side. It is served by two 75 ton pneumatic cranes and one of 30 tons capacity. It is furnished also with a large variety of machine tools of varying capacity, among which are some suitable for the heaviest class of work.

There is a planing tool here which can finish a piece of metal 13 feet wide, 13 feet high and 55 feet long, and a lathe will soon be completed capable of handling pieces 11 feet in diameter and 80 feet long. The work done in this building is chiefly that of rough ma-



CRANK AND THRUST SHAFTS FOR THE AMERICAN LINE STEAMERS "ST. LOUIS" AND "ST. PAUL."

chining or finishing miscellaneous forgings and finishing heavy cannon.

The armour forging and bending shop is 846 feet long by 116½ feet wide. This building houses heating furnaces, a 125 ton steam hammer, a 14,000 ton hydraulic press, the latter operated by a 15,000 horse-power pumping engine; a 7000 ton bending press, and a heavy plate rolling plant now in course of construction. All of these are of the largest type. They are used principally for the manufacture of armour plate and are served by hydraulic cranes of 150 tons capacity. Machine shop No. 3,—546 feet long by 63 feet wide, served by traveling cranes of 80 tons capacity, is devoted to the finishing of armour plate, forged in the building just mentioned.

Adjacent to these shops are the annealing ovens, tempering furnaces and oil baths. These are housed in a building 496 feet long by 63 feet wide, and are capable of treating armour plate of the largest dimensions, as well as shafts, gun tubes and similar forgings up to 55 feet in length.

It must be evident to the most uninitiated that before undertaking a project of such magnitude as above outlined, a thorough conception of the situation had to be possessed. The same consideration which had previously led to a change of product in the rail mill from iron to steel, held good in the latter instance. It was considered useless to temporise with iron for many reasons. The fact that these two metals could not be handled indiscriminately, side by side, in the same forge, became apparent as soon as familiarity was obtained with the requirements of their respective treatments. It was necessary also to have the workmen skilled in one direction only, so that their minds would not be dissipated by a multiplicity of methods of treatment.

The management soon became convinced, however, that if they handled steel only they would obtain work enough to keep them busy, and they built upon these lines. How well founded their conviction was, their success from the start has proved. They were, indeed, scarcely ready for work when they were called upon by the United States government to supply armour plate, gun forgings and marine engine parts for the navy, and heavy gun forgings for the army. Shortly afterwards, large work, in the nature of shafts, connecting rods, rings, cylinders, etc., was taken for private corporations, and as fast as they could prepare for it they were called upon to meet a demand upon them for smaller

forgings, and much work has been done and is now being turned out for the representative builders of steam and gas engines, pumps, compressors, elevators, mining machinery, machine tools of all kinds and miscellaneous parts of special machinery. It is to this commercial work that we will devote our attention for the present, as the methods adopted in turning it out are necessarily representative of the most modern practice, and it is these in which engineers, in general, are most interested.

Without entering specifically into the details of the difference between the processes used in forging iron and steel, it may be stated, in general terms, that with iron advantage is taken of its property of welding. Small pieces, previously heated, are piled upon one another and pressed together to form the finished piece, much as a clay model for a statue would be built up. On the other hand, steel does not possess this quality, and a piece large enough to make the finished forging must be obtained at the outset, just as a sculptor must have a block of marble large enough to enable him to chisel out his complete design.

The first consideration, then, in the production of miscellaneous steel forgings is to obtain pieces of steel, varying in size, but sufficiently large to be worked into the finished forgings which the general run of orders calls for. These pieces are called ingots, and are usually circular in cross section and vary in diameter and length according to requirement. To the formation of these ingots the greatest care is directed, for upon their composition and solidity depend the perfection of the finished forging.

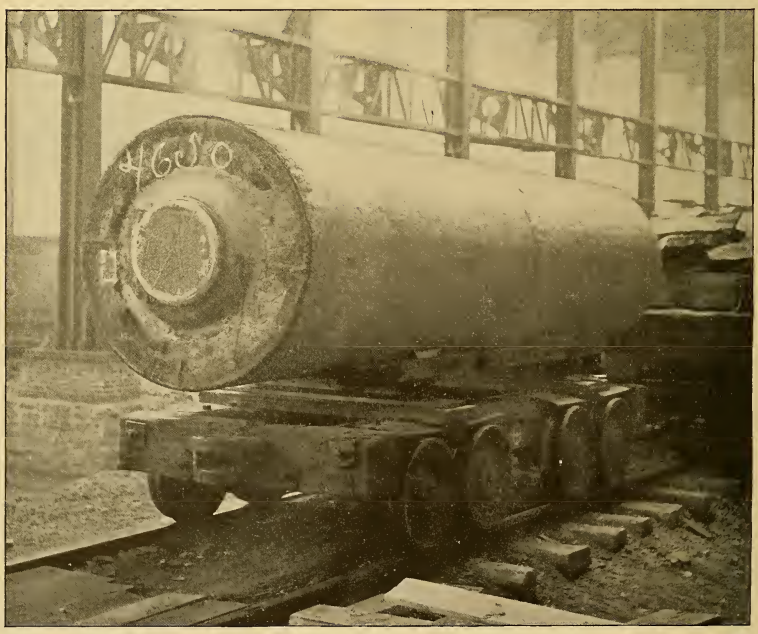
In the first place, the various ingredients of the steel, having been analysed carefully to ascertain in what proportions they should be mixed, are melted in what is called an open-hearth furnace. This is a rectangular basin of from 10 to 40 tons capacity, heated by gas generated in a separate plant, and so regulated in its supply that the temperature of the liquid mixture may be increased, diminished, or held stationary to suit conditions. By thus controlling the heat, some impurities can be burned out entirely, and others are allowed to remain in certain proportions. Thus from ten (0.10) to fifteen hundredths (0.15) of one per cent. of carbon makes a grade of steel that differs but little in its strength from wrought iron, while an increase in its percentage up to a certain limit tends to make it stronger, and beyond that, to make it hard and brittle. Too much phosphorus tends to make it brittle when cold, and sulphur to make

PROPELLER SHAFT FOR THE AMERICAN LINE STEAMERS "ST. LOUIS" AND "ST. PAUL." LENGTH, 53 FEET 5 INCHES. DIAMETER, 21 INCHES. THE SHAFT IS HOLLOW, HAVING A 6-INCH HOLE RUNNING THROUGH IT.

it so brittle, when hot, that it can not be forged properly. High grades of steel should not have more than .04 of 1 per cent. of these elements in it. Others of its chemical constituents affect it in similar and other ways. Their combination in proper proportions can be arrived at only from long experience in constant handling and by observing their subsequent effect on resultant forgings in actual service.

From time to time, during the process of melting, a small dipperful of the molten liquid is taken out of the furnace and rapidly tested, to ascertain how the refining is taking place, and when the charge is ready, it is poured into large ladles placed on cars which can be run directly over the moulds. These moulds may vary in diameter from one to six feet, and up to 20 feet, or more, in length, and great precautions have to be taken at this stage of the proceedings, particularly with the larger sizes, to prevent defects from forming in the cooling and solidifying mass.

It is evident, for instance, that in a body of metal of a large diameter, the outside will cool very rapidly, compared to the centre, and become solid, while the centre is still liquid. This cooling is accompanied by rapid contraction which, being resisted by the hotter metal on the inside and by friction against the mould, has a tendency to cause surface or skin cracks. Subsequently, as the metal within solidifies from the outside inwards, its tendency is to form cavities along the upper portion of the central axis, or line of last cooling. This defect is known as "piping." Air intrained while pour-



SOLID INGOT OF FLUID COMPRESSED STEEL, BEFORE BORING, USED FOR MAKING THE FORGED FIELD RING OF ONE OF THE LARGE NIAGARA ELECTRIC GENERATORS. LENGTH, 197 INCHES. DIAMETER, 54 INCHES. WEIGHT, 120,000 LBS.

COMPRESSED STEEL INGOT WITH HOLE BORED THROUGH CENTRE, PREPARATORY TO FORGING.

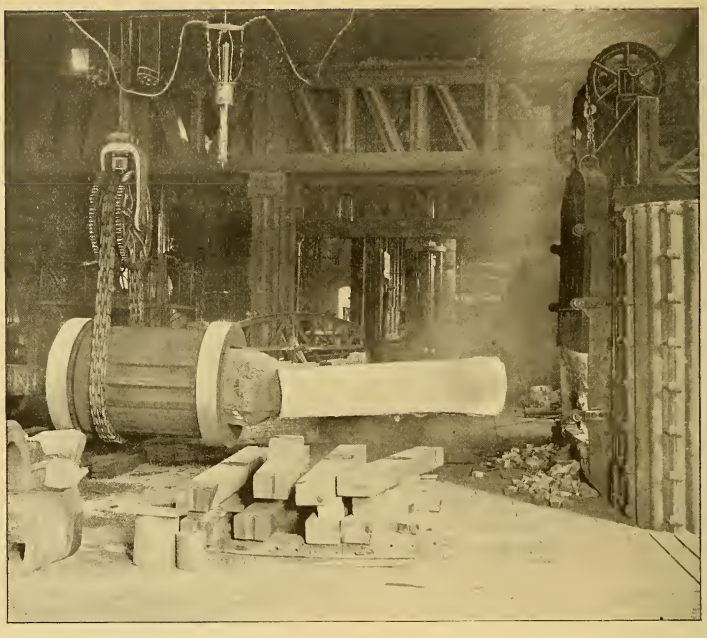
ing the liquid into the mould, and gases generated within the metal in cooling, cause what are known as blow holes. There also occurs a concentration of carbon and impurities towards the upper central portion of the ingot during slow cooling from a liquid condition, which is called "segregation." Various methods have been devised to avoid or control these defects in ordinary good practice, but, without doubt, the most efficient means is the use of the so-called Whitworth process of fluid compression.

In this process the ingot mould, as soon as it is filled with molten steel, is placed under a hydraulic press and there the fluid metal is subjected to as great a pressure as necessary, up to 7000 tons, until solidification takes place. Under this great pressure many defects are eliminated, and ingots are obtained which are more solid and homogeneous than those produced by any other means.

At first thought, it would be presumed that ingots for large hollow forgings would be cast hollow. It will be seen, however, that the tendency in a hollow casting would be to have surface defects not only on its outside, but also on its inside surface, and that, as the line of last cooling would be midway between the inside and outside surface, there would be also a tendency to the formation of an annular "pipe." It is, therefore, customary to cast such ingots solid and to bore them out. By this means the part of the metal along the core of the ingot, where defective material is most likely to exist, is removed.

In order to make a forging free from defects due to "piping" and "segregation," a large proportion of the ingot (about one-third) has to be discarded from the top, and cut off for remelting. Good practice also demands that the diameter of the ingot be about twice that of the forging.

In preparing the ingot for forging,



TAKING AN INGOT FROM A HEATING FURNACE TO BE FORGED.

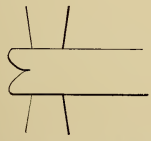
the first requisite is slow and uniform heating to the proper temperature. The same attention evidently must be observed in this process as was given to its original cooling,—one being simply the reverse of the other. The next requisite is the selection of forging tools of proper design and power for the work in hand. The pressure applied in shaping a body of steel should be sufficient in amount, and of such character, as to penetrate to the centre and cause flowing throughout the mass. As this flowing of the metal requires a certain amount of time, the requisite pressure should be maintained throughout a corresponding period.

The hydraulic press, therefore, is used instead of the hammer to work it into shape. Under its action the forging is slowly operated upon, and the pressure distributes itself evenly throughout the mass, whereas, under the high velocity of impact of the hammer the metal has not time to flow, and internal strains, if not always defects, are thereby created. In fact, the cause of failure of many forgings, particularly large ones, can often be attributed to their having been shaped under a hammer of insufficient power where the blow is developed by a high velocity, rather than by weight of falling mass.

The difference in the effect of these two methods of forging is apparent in large cylindrical shafts. Those forged under a hammer have concave ends, showing that the blow has not penetrated the forging, but has worked only upon the surface and drawn it out, leaving the central portion behind, and thus producing a tearing strain on the core by which actual cavities may be developed. The reverse is the case with a shaft that has been hydraulic forged. Its ends are either straight

or slightly convex. The pressure being definite and constant, and acting slowly but uniformly throughout the distance traversed by each stroke, passes completely through the forging and tends to force out the centre, that portion being hottest and, therefore, the softest. In order to ensure the most thorough working of the metal, large shafts and similar forgings should be made hollow, where practicable.

The production of such forgings is much facilitated by the use of the hydraulic press. The ingot bored as above described offers the best conditions to begin with. The thin walls are readily reheated, and the danger of internal cracking during that operation is removed. After reheating, a mandril is passed through the ingot and it is then worked down under the press, the diameter gradually decreasing and the length increasing proportionally. It is much more difficult to hollow forge with a hammer than with a press, especially in long lengths. A slow and even pressure is necessary to draw out the thin cylindrical walls equally and make a shaft which is straight and symmetrical throughout. During this change in shape, the metal must, of course, be reheated frequently. Operating on metal that has become too

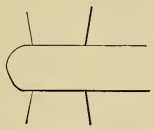


EFFECT OF FORGING A HEAVY SHAFT UNDER A LIGHT HAMMER.

cold to flow would only bruise and tear it.

When a large mass of steel has been forged to shape, it is apt to contain internal strains due to irregular cooling and its molecular or crystalline condition will lack uniformity and desirable physical qualities more or less according to the temperature at which the last work of forging has been done. To correct and modify these undesirable conditions, the forging must be annealed. This consists in heating it in a suitable furnace to a uniform and proper temperature and allowing it to cool slowly. All forgings should receive this treatment in order to improve their physical condition and to guard against strains developing after they have been in service, causing springing and possible rupture.

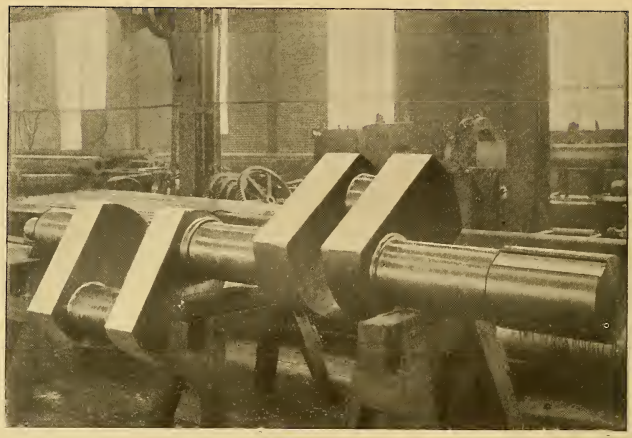
On the treatment of steel after forging largely depend its physical qualities. Of these, the most important to be considered are the "limit of elasticity" and the "elongation" and "contraction of area" which are the measures of "toughness." The limit of elasticity marks a point where the metal loses its elastic property of recovery after a load has been applied to it, and stretches permanently under subsequent stress. In an annealed forging of ordinary steel, the limit of elasticity is less than one-half the ultimate strength.



EFFECT OF FORGING A HEAVY SHAFT UNDER A PRESS.

In order to learn what are the physical qualities of a forging, a full-sized prolongation should be forged on the end and treated in all respects like the forging. From this prolongation, test specimens of a standard size are cut out cold by machining, and are actually pulled apart in a testing machine. The elastic limit and ultimate strength are carefully noted and after the pieces are broken, its stretch, or elongation, as well as its reduction in sectional area, or contraction, are recorded. Thus, from long experience and a careful comparison of physical qualities, as shown by testing, with chemical composition, metal possessing required properties can be produced with certainty.

In order to obtain the full benefit of the use of steel, a grade should be selected that has a high ultimate



DOUBLE-THROW CRANK SHAFT, MADE FOR THE DE LA VERGNE REFRIGERATING MACHINE COMPANY, NEW YORK CITY. WEIGHT, 9556 LBS.

strength and elastic limit, combined with ductility or toughness, as shown by a high percentage of elongation and contraction.

To develop these properties and the combination of them to the highest extent in any grade of steel, tempering, *i.e.*, hardening and annealing, is resorted to. This treatment consists, first, in heating the forging to a certain temperature which experience has shown to be proper according to circumstances, and cooling it rapidly by plunging it into a bath of oil or other suitable liquid; and, second, in annealing by again heating and cooling slowly. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition, existing after forging, is broken up and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionally to the tensile strength and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area.

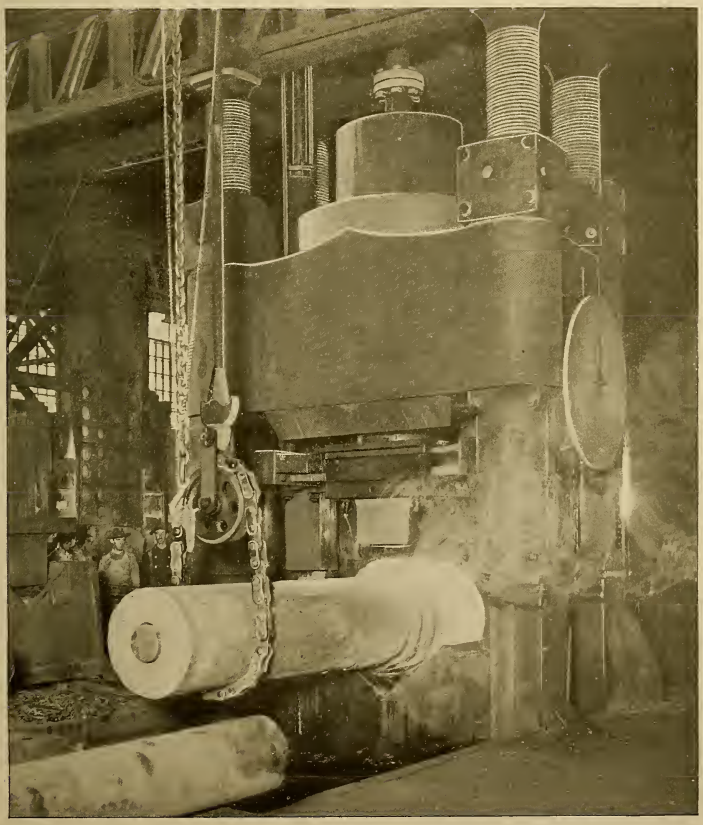
In order to avoid what may result in dangerous internal strains occurring during the process of tempering, the sectional thickness of the metal should be reduced and made as uniform as possible. This leads, in the case of shafts and similar forgings, to the use of axial holes either bored or produced by hollow forging. Indeed, tempering in general can not be safely applied without such axial holes, and it is evident that the combination of hollow forging and tempering will insure the very best results.

With the substitution of steel for wrought iron in engine and machine forgings, the tendency has naturally been to use a mild or soft steel, approaching iron as regards physical qualities, and in the ease with which it can be machined. Wrought iron has a low elastic limit, averaging, in thick sections, about 20,000 lbs. per square inch.

Although mild steel, when of good quality and properly worked and treated, is superior to wrought iron in strength, toughness, homogeneity and freedom from imperfect welds and porous spots enclosing slag and scale, still it does not possess the very desirable quality of high elastic

strength combined with ductility or toughness in as great a degree as can be obtained without danger in a harder steel, when proper precautions are taken in its manufacture. In other words, in the use of ordinary mild steel, only a partial advantage is taken of the most desirable qualities of steel which are easily within reach.

In some instances, where the amount of machine work in finishing is very great, and where there is ample margin of safety in the design, the use of mild steel may be advisable. Such steel contains about 0.20 to 0.25 of 1 per cent. carbon, and can be guaranteed to show, in specimens four diameters in length, cut from full-sized prolongation of forgings or from representative pieces, a tensile strength of not less than 57,000 lbs. per square inch, and an elastic limit of not less than 27,000 lbs. per square inch, with an average elongation of 28 per cent. For the general run of engine forgings, however, a harder steel should be used, in



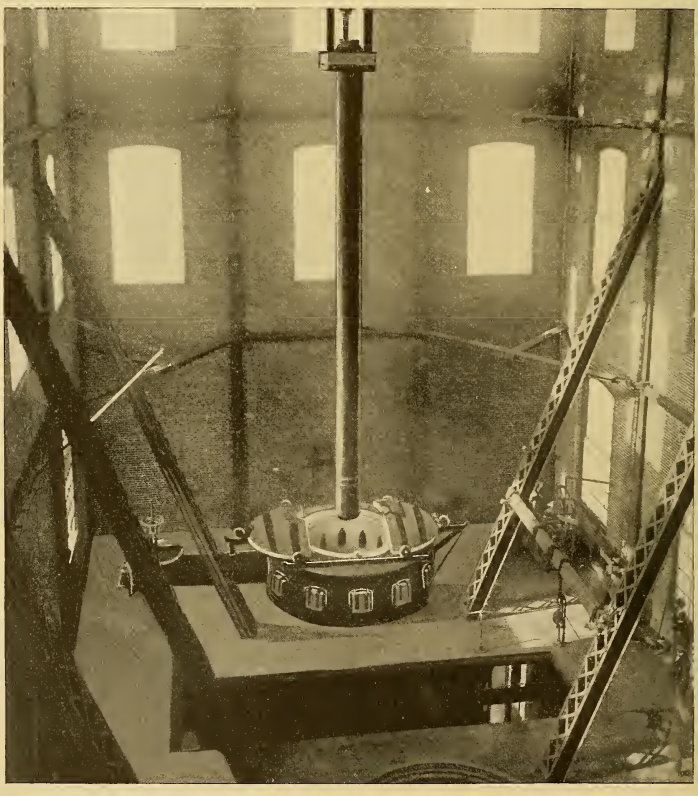
HOLLOW-FORGING A SHAFT UNDER A 5002-TON HYDRAULIC PRESS.

which a tensile strength of about 75,000 lbs. and an elastic limit of 35,000 lbs. per square inch can be obtained, together with an average elongation of 25 per cent. in four diameters.

When proper precautions are employed, forgings can be made with perfect safety of a still higher grade of steel, and this is especially recommended for crank and cross head pins and for all parts subject to severe alternating strains and wearing action. In this grade of steel, a tensile strength of about 85,000 lbs. and an elastic limit of about 40,000 lbs. per square inch can be obtained, with an elongation of 20 per cent. in four diameters.

If the shape of the forgings will allow of their being tempered they will possess still higher qualities than those above mentioned, and can be furnished with a tensile strength of from 85,000 to 90,000 lbs., an elastic limit of 45,000 lbs. per square inch, and an elongation of 23 per cent. in four diameters.

By the introduction of nickel into steel, a further marked improvement in



TEMPERING A SHAFT IN OIL.

the combination of physical properties can be attained. The effect of certain percentages of nickel in mild steel is to add both strength and toughness. This is indicated in test specimens by an increase in elastic limit proportionally to ultimate strength, combined with a higher elongation and contraction of area. By the combination of hollow forging and tempering nickel steel, a material is obtained excelling all others known in elastic strength and toughness.

A LIGHT AND STRONG SHAFT OR ROLL.

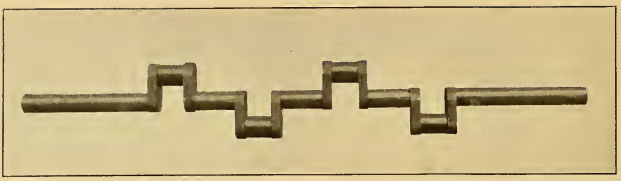
As an example of this can be mentioned the shafts made for the U. S. warship *Brooklyn*. These are 17 inches outside diameter, 11 inches inside diameter, and 39 ft. long, weighing, each, 19,112 lbs. These shafts showed, in specimens cut from full-sized prolongations, a tensile strength of 94,245 lbs., an elastic limit of 60,775 lbs. per square inch, an elongation of 25.55 per cent., and a contraction of area of 60.58 per cent.

Fluid compressed oil tempered steel, containing from 0.40 to 0 45 of 1 per cent. carbon, and especially nickel steel, is markedly adapted for piston rods of rock drills, hammer rods, stamp stems, cam shafts, crank and crosshead pins, and similar pieces that are subjected to stresses alternating between tension and compression, or of either kind frequently repeated. By substituting steel of this grade, which can be given an elastic limit of from 50,000 to 60,000 lbs. per square inch, for wrought iron or mild steel, which is generally used for the purpose, the best results can be obtained.

Prominent among hollow forgings made by the Bethlehem Iron Company are the Ferris wheel shaft, 32 inches outside diameter, 16 inches inside diameter, 45 ft. long, weighing 89,320 lbs., and the shafts for the steamers *Puritan*, *Plymouth* and *Pilgrim* of the Old Colony Steamboat Company. These are 30½ inches outside diameter, 12 inches inside diameter, and weigh 65,832 lbs. each. Field-rings of nickel steel were hollow forged for the 5000 H. P. Westinghouse dynamos at Niagara Falls. These rings are 11 ft. 7⅜ inches in diameter, 4⅛ inches thick and 4 ft. 2¾ inches wide, and weigh 28,840 lbs. each.

NICKEL STEEL FIELD RING FORGED WITHOUT A WELD FOR ONE OF THE 5000 H. P. NIAGARA GENERATORS. DIAMETER, 11 FEET 7⅜ INCHES. WIDTH, 4 FEET 2¾ INCHES. WEIGHT, 28,840 LBS.

Shafts for the United States Navy are made hollow, and those for the American Line steamers *New York*, *Paris*, *St. Louis* and *St. Paul* are 21

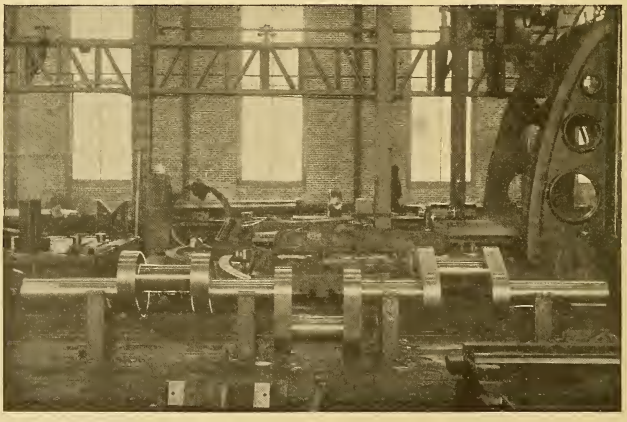


CRANK SHAFT FOR A 100 H. P. GAS ENGINE, MADE FOR THE J. I. CASE THRESHING MACHINE CO., RACINE, WIS. U. S. A.

inches in diameter. The crank pins are 22 inches in diameter. There are 10-inch holes through both. Undoubtedly the best type of hollow forged shafts and one which is gradually being introduced is where the walls are of the same thickness throughout, the outside and inside diameter varying together, both being greatest at the centre where most strength is required, and smallest at the bearings. Such a shaft is designed on the principle of a girder and offers the greatest strength for the least amount of metal. Rolls for plate mills, made after this design, are especially desirable.

A large proportion of the material produced by the forging department at the Bethlehem Works has been manufactured under the rigid inspection of officers of the American navy and army and of foreign governments. This has necessitated a very large amount of experimental and prescribed testing under all conditions of manufacture, and has rendered it absolutely necessary to hold the work in all its stages under the most careful and complete control from the ore to the finished product. This experience is now being constantly applied to the production of mercantile work and affords an opportunity to engineers to procure with certainty and uniformity material possessing higher physical qualities than ever before.

This allows a wider scope to new designs and a simplification and lightening of old patterns. Thus the field of engineering is broadened and the effect of enterprise on the part of one corporation is felt in the development of all other lines of trade wherever machinery finds a place.

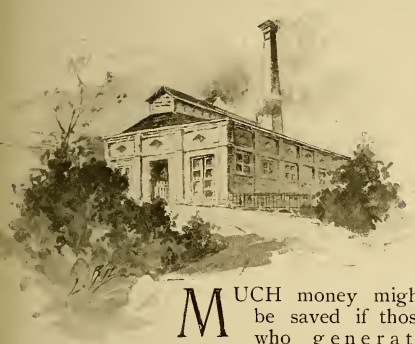


A THREE-THROW CRANK SHAFT, MADE FOR THE POPE MFG. CO., HARTFORD, CONN., U. S. A.

STEAM RAISING.

Practical Hints on Preventable Losses.

By Bryan Donkin, M. Inst. C. E.



MUCH money might be saved if those who generate steam would undertake proper experiments, and realise that coal is only heat in a solid form, and should be bought as such. Their object ought to be to turn the fuel to the best account in evaporating the largest quantity of water,—in other words, to obtain the maximum boiler efficiency at the minimum cost. The steam formed should be conveyed in well-covered pipes to the engine cylinders, to obtain the maximum power with the minimum condensation.

The fuel should be purchased with as little clinker, dirt and moisture as possible, and considered as so many tons, not only of fuel, but also of heat. It should then be burnt according to the well-known chemical laws of combustion. The weights of coal, clinker, and water evaporated should all be known, and carefully recorded in a book at the end of each day and each week. This is now done in well-arranged boiler houses, but only in relatively few cases. On the European Continent it is much more usual.

All fuels contain a certain proportion of dirt, clinker, and incombustible matter. This varies in England from 3 to 15 per cent. and even 20 per cent. by weight, so that a purchaser is always paying a high price for so much useless dirt, which he very rarely measures, and often has to pay to get rid of. This percentage of useless matter should be known and specified between buyer and seller. Fuel is purchased only because, by combustion, it generates heat. The amount of such heat per pound of fuel ought to be determined, and should govern the price of the fuel.

There are now reliable instruments, called fuel calorimeters, which give the heating value of any fuel. The price should be fixed, not as at present, at so much per ton, but according to the heating value of the coal, taking into account the percentage of incombustible matter and dirt. One of the best English coals,—Nixon's Navigation Welsh,—has a heating value of 15,600 British thermal units per pound, equal to an evaporation of 16 lbs. of water per pound of pure and dry coal, from and at a temperature of 212° F. The buyer should purchase fuel with a minimum amount of dirt, and a maximum amount of heat.

The Belgian State Railways and many other lines and factories on the European continent buy all their coal on this basis. When will the English and American people follow this logical system, and not purchase their fuel, ignorant, not only of its heating value, but of the percentage of dirt? The calorific value of English coals may be taken as varying approximately from 15,550 to 10,000 B. T. U. per lb. The

first is equal to an evaporation of 16 lbs. of water from and at 212° F. and the latter to 10⅓ lbs. This is the net calorimetric heating value of the coal of which ordinary boilers in practice give only from 60 to 70 per cent.

Grate Losses.

The grate should always be well covered with fuel. Ordinary grates generally allow too large a quantity of cold air to enter, partly because the bars are not covered, and often because they are too wide apart. All the cold air passing the grate, in excess of that necessary for the proper combustion of the fuel, causes loss and waste, as it carries off heat from the boiler. From an analysis of the coal and gases this excess of air can be determined, and this plan is often followed in many well-managed establishments.

Firing, Stoking, Damper and Clinker Losses.

The fire doors should be kept open as short a time as possible, to reduce the waste caused by letting in cold air. The less dirt there is in the coal, the less frequently will the fires require cleaning, and the more perfect will be the combustion. Attention should be paid to the opening of the damper, so as not to have too much draught and, therefore, too much air admitted, particularly with a high chimney. The fires should be kept as hot as possible, and the thickness of coal on the grate should be carefully regulated.

Heating Surfaces.

The hot gases should be well distributed over the heating surface of the boiler, whatever type is used, and particularly in a water tube boiler. The problem is to make the surfaces absorb as much heat as possible from the gases, —in other words, to facilitate the transmission of heat from the dry absorbing surfaces of the boiler plate on one side, to the heat transmitting or water surfaces, on the other. As is well known by practical tests, these surfaces transmit very much more heat when clean than when dirty or covered with scale. Care should, therefore, be taken to remove periodically the soot and dirt from all the external, and any lime or deposit from the internal, surfaces. These impurities are very bad conductors of heat and all surfaces of tubes, fire-boxes, etc., should be kept as clean as possible. Any accumulation of dirt is a great cause of waste. These surfaces being out of sight are generally forgotten, and become very foul, heat transmission is much checked, and the gases are allowed to escape at too high a temperature.

Smoke and Chimney Wastes.

Volumes of black smoke are a disgrace to heat engineers. Although the actual quantity of carbon wasted in such smoke is very small, as has been proved by experiments, smoke generally means some waste of heat, and is a consequence of imperfect combustion. To prove how imperfect the combustion is, it is most important that the chimney gases should be analysed periodically, to ascertain, not only the percentage of air passing through the boiler to waste, but especially the amount of carbonic acid and carbonic oxide. In well managed establishments this is now done, in order that with the particular fuel used, the stoking may be carried out to obtain the maximum amount of carbonic acid and the minimum amount of oxygen and carbonic oxide. The expense of an apparatus for analysing and sampling the gases is not great, and is covered, in a few days or weeks, by the fuel saved. The following list gives the results of analyses of gases from various boilers.

Table of Analyses of Gases from Various Types of Steam Boilers.

Type of Boiler.	CO_2. Carbonic acid per cent. vol.	CO. Carbonic oxide per cent. vol.	O. Oxygen per cent. vol.
36 Lancashire boilers	6 to 14	Zero to 0.4	4 to 12
6 Cornish boilers	7 to 15	Zero to 0.3	3 to 12
1 Vertical boiler	10½	3	6
1 Tubular marine boiler	8½	0	10½
13 Loco. type boilers	6 to 16	0 to 1	2 to 12
17 Water tube boilers	7 to 12	0 to 1	6 to 12
2 Multitubular boilers	6 to 9	0	6 to 10

With good combustion, the amount of carbonic acid should be from 12 to 16

per cent. by volume ; the amount of carbonic oxide should be zero, and the percentage of oxygen as small as possible. The waste of fuel from incomplete combustion and low percentage of carbonic acid is often as much as 12 or 15 per cent. and sometimes more.

Next we come to the question of the temperature of the escaping gases, which should be taken at the end of the boiler. If this temperature be too high, a large saving can be effected by adding an economiser or feed water heater.

The writer has often found an economy of from 10 to 12 per cent. due to a rise in the temperature of the feed water and to a reduction of the temperature of the escaping gases, which would otherwise carry off heat to waste. Few boiler engineers and boiler owners ever take the temperature of their gases, and still fewer analyse them. They look after 1 or 2 per cent. discounts in their ordinary trade accounts or bills, but often and thoughtlessly submit to constantly preventable wastes in their boiler houses of from 10 to 20 per cent. on the fuel account.

To ascertain the amount of draught, or the vacuum, in any chimney, a U-glass water gauge, costing a few shillings, should always be fixed to the bottom of the chimney. This draught varies from 0.2 inch in low and small chimneys, to 0.7-inch in high and large chimneys. "Good" or "bad" draught are very vague terms. The draught should always be defined in tenths of inches of water. For maximum economy the temperature of the escaping gases at the end of any boiler should be only a little above the temperature of the steam generated, say 40° or 50°. Take a boiler working at 100 lbs. pressure ; the steam temperature would be about 338° F., and in this case an economical temperature for the escaping gases would be 380° or 400° F. Supposing, as often happens, that they escape at 540° above the atmospheric temperature, and that the amount of carbonic acid is 8 per cent.—a usual condition. The percentage of loss will then be about 23 per cent., a large proportion of which could be saved.

Radiation and Air Leakage Losses.

The external brickwork of a boiler should be carefully examined at stated intervals, say every week, and any cracks or openings between boiler and brickwork should be stopped, to prevent leakages and currents of cold air passing into the flues and carrying off the heat from the boiler. Such an examination can be made by the stoker at practically no cost. The front of the boiler, the top and all external surfaces, should be well covered to minimise losses by radiation. These losses from boiler and brickwork may easily amount to from 8 to 10 per cent. of the total heat in the fuel, depending upon how the boiler is set, and the extent of the external surfaces of brickwork.

Feed-Water Measurement.

The sole object of a boiler is to evaporate water into steam by the heat of the fuel ; yet how few engineers or mill-owners ever measure the feed-water pumped in ! This may be done by two methods, tanks or water-meters. Where great accuracy is required tanks are the best ; if water-meters are used, the best piston type should be selected, brass lined. Water-meters have nearly always a small error, plus or minus, which should be ascertained from time to time and allowed for. In any important experiment the water-meter should be tested both before and after. In all well-managed boiler plants the feed-water ought to be regularly measured and comparisons made, which always lead to economy. The writer knows of several scores of cases where the boiler-feed is systematically recorded. When the quantity of water evaporated per hour and the total heating surface of the boiler are known, the pounds of water per square foot of heating surface per hour can be calculated. For the most economical results this should not exceed from 4½ to 5 lbs. A greater evaporation generally leads to waste up the chimney, unless an economiser be used.

Boiler Efficiency.

To compare the evaporation results of different types of boilers, using different fuels, it is very necessary to have some recognised standard. In the writer's opinion what is called "boiler efficiency" is the best standard of comparison for reporting boiler results. The efficiency of a boiler is the percentage or ratio of the total heat that any given fuel can generate by complete combustion, to that part which is usefully employed in heating and evaporating the water into steam. In this way, good or bad boilers, burning different fuels, with different stokers and different chimney draughts, can be readily compared. The efficiency of the same boiler with the same fuel and stoker can also be compared, when forced or worked easily. Therefore, to determine the boiler efficiency, it is necessary only to know the total fuel and water used per hour and the heating value of the fuel.

Some engineers take as the standard for comparing boilers, the number of pounds of water evaporated, from a certain temperature, per pound of fuel, but if this be made the basis, no account is taken of dirt or clinker in the fuel or of its heating value, and the results are, therefore, misleading. A very simple trial gives the total fuel burnt per hour, and the total water evaporated. The fuel is known, by a fuel calorimeter to contain so much heat; therefore, on one side of the account, so much heat is given to the boiler per hour. Let us next examine what becomes of it. Seventy-five per cent. may have been found in the water evaporated into steam; about 15 per cent. up the chimney to pure waste; and the balance, 10 per cent., was probably lost in radiation. In this case the boiler efficiency would be 75 per cent., a rather exceptional result, since 80 per cent. is generally a maximum with the best arranged boiler plants, and good combustion. From 50 to 60 per cent. is very usual, and this means, that in many cases only half, or a little more than half, of all the available heat in the fuel is utilised.

Commercial men, with business capacity, should look after these heat losses and serious preventable wastes, and the small cost incurred in investigations and necessary experiments would soon be covered many times over. In the United Kingdom there are said to be from 140,000 to 150,000 land steam boilers, excluding running locomotives. The question of preventable wastes in boilers is, therefore, not a small one.

ELECTRIC CURRENT SUPPLY FROM CENTRAL STATIONS.

By John W. Lieb, Jr.

THE operations involved in the business of the supply of electric current from a central station for transformation into heat, light and power divide themselves readily into two broad divisions—generation, or manufacture, and distribution, or subdivision.

Discussing these recently, in a paper presented to the New York Electrical Society, the author pointed out that the generation, or manufacture, of current includes the cycle of operations conducted within the station itself, involves the transformation of the heat energy stored in the coal into dynamic energy, its transformation into electric energy and its delivery to the switchboard. The operations involved in the distribution of the current are effected mainly outside the station, and involve its delivery through a network of mains and secondary conductors to the local centres of consumption, where, through

translating devices, the current is transformed into the form of energy desired —light or dynamic energy.

The various processes involving the generation of electric current on a scale rendering possible its industrial utilisation are, except where water power is available, the direct results of chemical action—usually the combustion of coal. The operations that a central station conducts are the economical burning of coal, the imparting of its heat energy to the water in the boiler, converting it into steam, the dynamic force of which impels the piston of the engine, resulting in the movement of conductors through the lines of force of an electromagnet, thereby generating electric current.

Of the several steps of this cycle the important ones are mechanical. The economical burning of coal on a grate, although a chemical process, has been reduced, by accepted types of boiler furnaces, to a mechanical operation requiring some common sense and a stout arm, but no mechanical formula. The electric generators involved are relatively simple, and the perfection which electrical construction has already attained, has confined further possibilities in this direction to improvements affecting the investment rather than operating accounts. I speak of this somewhat elementary proposition for the purpose of calling to mind and emphasising the fact that in the modern central station the problems within the station—problems of generation or manufacture—are in mechanical rather than electrical engineering.

The best types of multi-expansion condensing engines rarely transform more than 15 or 16 per cent. of the heat energy of the coal into dynamic energy, and, in the common forms of non-condensing engines, not more than six per cent. of the coal energy is available at the flywheel of the engine. Under the conditions found in most electric light stations these efficiencies can not be approached. Taking into account the variable loads on engines and boilers, condensation in steam pipes with the other losses, the total efficiency of the transformation into electric current seldom, if ever, exceeds eight per cent. and is usually not greater than three per cent.

The electrical efficiency of the best types of dynamos of the size used in the larger stations is seldom less than 90 per cent. and, in the larger sizes, is as high as 96 per cent. These efficiencies diminish but little under the partial loads ordinarily carried in a well designed station having generating units of several sizes to maintain a high ratio of capacity to output.

It is safe to say that of the energy delivered to the engine shaft, from 75 to 85 per cent. in the smaller stations, and from 85 to 90 per cent. in the larger, is delivered as electrical energy to the switchboard, including losses due to the inefficiency of the dynamos, in the leads to the switchboard, in the contacts, etc. It is evident, therefore, that the losses due to the inefficiency of the electrical apparatus in the station are small as compared with those due to the inefficiency of the apparatus engaged in the conversion of heat energy into dynamic energy, and in the auxilary apparatus. The great problem in the mechanical operation of a station is to reduce these losses to a minimum, approaching as near as possible the conditions of the maximum economy—the coal consumption, per unit generated approaching what its value would be if the whole station were operated at the load of maximum efficiency for the 24 hours.

The problems which are more specifically electrical in their nature are those connected with the delivery of the current from the switchboard into the system of mains and feeders which distribute the current to the consumer's premises and its transformation there in the form of energy desired.

The loss of energy in the conduction of current from the switchboard to the point of consumption depends upon the factors, current, pressure, sectional area of conductors, and their length. For each particular case there exists a fairly definite relation, from which, given the cost of producing the current, the aver-

age use of current, or the load factor, the distance to the point of consumption, and the cost of the conductor per unit area, the most economical section can be determined. It would, of course, be out of the question to make this calculation for each consumer, or group of consumers, but it must be taken into account when it is a question of supplying current at considerable distances from the station.

Erroneous ideas are held as to what the actual losses are in a network of feeders, mains, and services distributing current from any station. It may be interesting to note that the drop of voltage, due to resistance of conductors between the switchboard and the consumers' services on the Edison system in New York, amounted to an average of seven per cent. during 1895. To this should be added an average drop of two to two and one-half per cent. on the consumers' wiring between the service and the lamps. This drop has been reduced considerably, as well as the investment cost for conductors, by the use of two or three "bus" pressures in the modern station, grouping the distant, or heavily loaded, feeders on the "bus" carrying the high voltage, and the short, or lightly loaded, feeders on the low "bus." The same result is obtained by the use of a "booster" inserted in series with the feeder, which adds to the "bus" pressure the voltage necessary to overcome the drop.

Notwithstanding the much-talked-of leveling of the station load curve, due to the installation of motors, it will be found that as a station increases in capacity, the ratio of maximum load at any time to the total connected installation will continue to fall. There is a limit, of course, beyond which this decrease is not likely to go, depending largely on the further uses to which electricity will be applied.

In an industrial district, where the motor load is heavy nearly all day, the lighting load is comparatively light, except during the winter, when darkness sets in early, and the motor and lighting loads overlap. In a district of this kind, moreover, there is but small demand for light at night. In a residential or shopping district, on the contrary, the motor load is of less importance and the lighting load becomes great immediately upon the approach of darkness, reaching a maximum in the evening and extending into the night.

Although motor service is, on the whole, advantageous to a station, owing to the long average use in proportion to the time of maximum current demand, and can, therefore, be sold at a considerably lessened rate than in the case of arc or incandescent lighting, it is not an ideal service. This is due to the fact that the motor load overlaps the period of maximum demand for lighting, and, therefore becomes part of the maximum load of the station, for which generating and distributing capacity must be provided. The ideal service for leveling the load curve, which all station managers are striving to do, is one which ceases before the time of maximum lighting, and which would not, therefore, call for additional and special investment. It is hoped that some such application may appear in the many uses which are being found from time to time for the electric current.

COMPRESSED AIR FOR STREET RAILROADS.

By Whitfield Price Pressinger.

THE rapid increase of population and the extension in area of many cities have brought in their trace a problem, prominent not only in the minds of those intrusted with the administration of municipal affairs, but of considerable importance to the shrewd capitalists in control of valuable franchises and to the citizens desirous of local transportation, economically, comfortably and expeditiously. So quickly has the addition in numbers and consequent widening of corporate limits come upon us, that we have been compelled to make a virtue of expedient, and adopt methods, which, though they be but temporary, nevertheless operate to relieve the tension caused by the rapidly changing conditions.

The growth and development of a municipality being so largely dependent upon rapid transit, and capital being always ready for such an apparently lucrative avenue of investment, it is not surprising that a considerable number of diverse methods of street car propulsion have been devised and exploited. The trolley, the electric storage system, the ammonia motor and several types of gas-engine motors, are but a few of the many creations of inventive minds in this direction.

But the advanced methods of street car locomotion in general operation to-day are practically represented by two systems,—the electric trolley and the underground cable. Of these, the first, insuring, as it does, manifest economy over previously existing conditions, and a most gratifying increase in speed, has received widespread adoption through the efforts of promoters, who have changed the equipment of existing lines and installed new ones upon a basis highly profitable to themselves.

That some prevailing objectionable characteristics of the trolley system, both from the standpoint of the company and of the passenger, will be removed in time, is undoubtedly true, but there will always exist features, peculiar to the system, and consequently ineradicable, which are condemned by the public. The unsightly wires, the cumbersome trolley poles and the heavy mortality record will always be viewed with popular disapproval, and a mathematical demonstration of reduced operating cost per car mile is to the magnate whose capital is involved a most eloquent argument for a change of system.

The underground trolley is said to represent a solution of the question and to demand a final recognition of the claims advanced for electricity in this service. This method has been recently in the interesting process of demonstration, and should it successfully undergo the crucial tests, a marked advance will be recorded for the electric system from the citizen's point of view though the enormous cost of installation will still remain a most portentous objection for corporations in smaller cities to overcome.

The cable system, approved by several large cities, with the prestige of efficient service satisfactorily rendered, stands pre-eminent to-day as the most advanced practical solution of the problem. But a comparison of the conditions existing in a great city with enormous traffic and close headway, as against the lighter traffic of smaller towns, in which the subject of rapid transit is of equal import, immediately discloses the objection to the cable system in the capitalistic mind, the cost of installation being practically the same in either case. Therefore, any system of street car propulsion, to

merit favourable consideration in competition with the two prevailing methods, must be capable of installation and operation at a lower cost. We are always confronted with the possibility of some neglected gentleman of scientific attainments and advanced ideas turning the whole or any part of our scheme of civilisation topsy-turvy, but at the present writing, passing from the trolley and cable systems, we naturally turn to the next important method of power transmission—compressed air. But before we discuss its application to street car service, let us consider the power itself.

Compressed air does not scintillate with the unknown possibilities which have been electricity's chief attraction to the imaginative mind of embryo genius. Its limits are clearly defined. Hedged in by unswerving mechanical and thermo-dynamic laws, presenting no avenues of research for the accomplishment of results hitherto unattained, compressed air, though longer known to science, has been overshadowed by its more showy contemporary. But the boundaries of electrical possibility in the sphere of mechanics are more clearly defined, and to-day the field of usefulness of compressed air exhibits a marked extension. It occupies a recognised position in almost every branch of the arts, sciences and manufactures, and many new and important methods and processes are based upon the utilisation of this power.

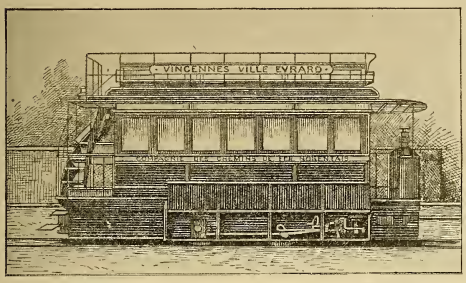
Compressed air locomotives for mine service are used extensively and, at their present stage of development, run anywhere from one to three miles with one charge of air, hauling loads which may vary from 50 to 100 tons, and surmounting any grades that steam locomotives can travel with economy. These compressed air motors in mines possess very great advantages over other systems of haulage. The annoyance of smoke and steam being entirely banished, and an increased supply of fresh air substituted, the air locomotive has, at the same time, all the desirable features of the steam-driven one, being an independent machine, containing its own power and being capable of running anywhere in the mine where tracks are laid.

But the very greatest point in favour of compressed air locomotives is their absolute safety from fire, which cannot be claimed for any other form of motor, either steam or electric. Pneumatic locomotives can be used both in the main and cross entries of mines, running into the mine room to gather loaded and to deliver empty cars. This is impracticable with any other system of mechanical haulage. On plantations, wharfs, and in other outside work, they are frequently employed in hauling cotton bales or other inflammable material, where risk of fire would militate against any other method.

In street railroad service, the misfortunes previously alluded to, seem to have clung to compressed air so tenaciously that a fair and impartial demonstration is yet to be made. In this employment it can present no arbitrary claims for its adoption, but must compete on an equal footing with established methods, the basis of comparison being cost of installation and operation. When the inventor, who undertakes to design and construct a compressed air street motor, is able to convince street railroad capitalists by an actual demonstration that his system can be installed and successfully operated at a reduced cost per car run, then, and then only, will compressed air be used in this service. The history of the various compressed air motors which have been exploited from time to time, is a checkered one, but the fact that compressed air yet lacks a thorough demonstration, is due either to incompetent efforts, or to causes entirely foreign and beyond the control of those interested.

The first to be tried, in America at least, was the Hardie motor, which was constructed at the Baldwin Locomotive Works, at Philadelphia, and tested in New York city about 1881. Subsequently the Judson system, taking its power from a continuous compressed air conduit the entire length of the line, was tested and abandoned. Then the Atmospheric Propulsion

Company built an experimental car and progressed no further. The rights of the Mekarski system, extensively used in France, are controlled in the United States and cars have been run there,



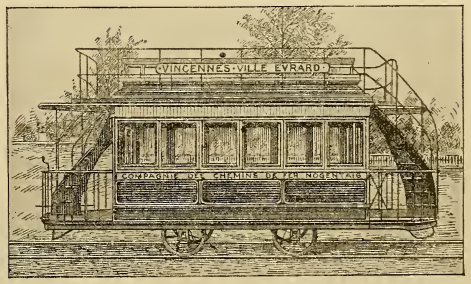
A MEKARSKI COMPRESSED AIR STREET CAR ON THE NANTES AND VINCENNES LINE, FRANCE.

but it has not flourished as in the land of its conception.

All these motors, with the exception of the Judson, were designed upon the storage system, being provided with cylindrical receivers carried under the car body. These receivers were charged at a central station with compressed air to a high pressure and the air was supplied to the motor cylinder on the car, at the requisite working pressure, by means of pressure-reducing valves. Provision was made for restoring the radiated heat energy to the air before it was used and air brakes were employed. On down grades no air was consumed and, in fact, the motor cylinders could be utilised as compressing pumps, to restore air under pressure to the receivers whenever the car was propelled by gravity. The entire mechanism was controlled by the motorman from his place on the front platform and required no higher grade of ability than in managing a cable or trolley car.

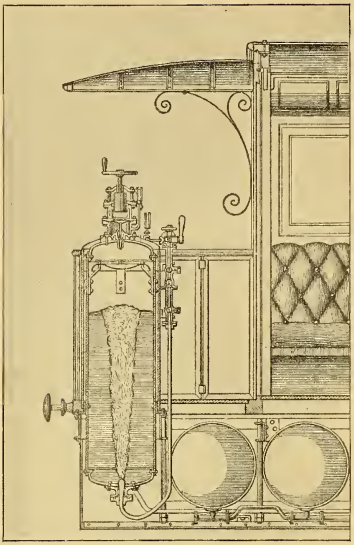
In this employment of compressed air power, as in others, Continental Europe and particularly France, made the earliest demonstration of any magnitude. In the suburbs of Paris and at Nantes, compressed air tramways have been in operation for several years. A report relative to the tramway near Paris, states that the many advantages of this system have been fully established by over two years' experience, and claims the following :—

"The motor does not emit smoke or hot gases, and is almost noiseless. Any desired rate of speed can be attained, and may be varied at will to suit conditions. A special track or overhead appliance is unnecessary. Being very light, it can be easily handled on steep grades. Simple in form, it does not frighten horses ; the machinery on the front platform is almost invisible from the outside. A possible explosion of compressed air is less dangerous than one of steam or superheated water. One person only is required to manage the machinery, and he need not necessarily be a skilled engineer. On crowded days or hours of the day, the accommodation for the passengers may be easily augmented by the addition of one, or even two, tenders, or ordinary cars."



A FRENCH TENDER CAR.

The principle of the system is very simple. The storage reservoirs of the



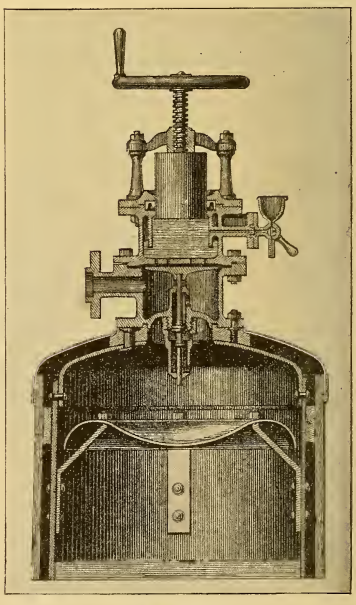
END OF ONE OF THE FRENCH CARS, SHOWING THE HEATER.

car are charged with compressed air at the supply station, to a pressure of 45 atmospheres. The air is reduced to a working pressure of from 5 to 10 atmospheres, being at the same time heated to a high temperature and charged with moisture in a heating vessel (voillotte) designed for the purpose. Thence the air passes to a double-expansion engine, expending its power in driving a piston in a manner exactly similar to steam. The average grade over which this motor travels is about 31 feet per mile.

The line at Nantes, operating Mekarski motors, has an average grade of about 25 feet per mile. In either case, however, the grade presents no difficulty in the regular operation of the cars, though the ascent in some parts of the road is quite abrupt. The rails used in these French lines are heavier than those employed in the United States, but the use of the compressed air system in the latter country would not necessitate a change in the tracks. The French cars, though comfortable, are unnecessarily clumsy and of excessive weight.

A new method of compressed air traction has recently been tried in Paris. The system is known as the Popp-Conti, being the joint invention of Mr. Victor Popp, whose name is so thoroughly identified with the Paris compressed air power system, and Mr. James Conti. The details of their invention vary from the other prominent methods, in that a low air pressure is employed, the car reservoirs being re-charged automatically at intervals along the line. It is stated that the preliminary demonstration has resulted so satisfactorily that a concession to the company controlling the system has been granted by the municipality of St. Quentin. The American rights for the system have been secured, and an engineer familiar with its details is now in the United States.

The new and modernised Hardie



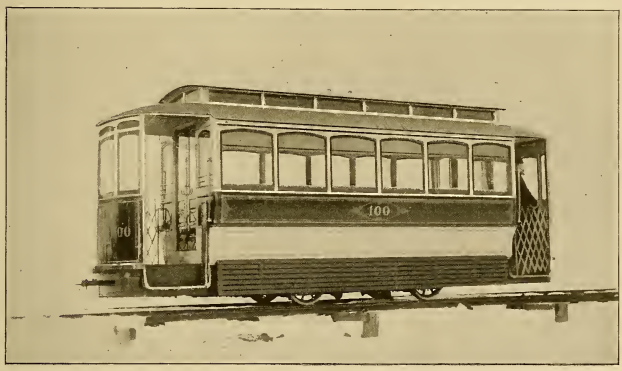
THE REGULATOR.

motor, too, has been much heralded there. This motor is built by the General Compressed Air Company, of Rome, N. Y., and is briefly described in a report by Capt. G. J. Fieberger, Corps of Engineers, U. S. A., as follows :—

"The motor examined is of about eight and one-half tons weight. The compressed air is stored in cylindrical cases of steel—Mannesmann bottles—from which it passes, through reducing valves, into a hot water tank placed under the body of the car. From this tank it passes through the tubes to the valves located upon each of the platforms, and thence to the engines.

"The operating mechanism occupies less space on the platform than that of the ordinary electric motor. The engines are placed under the car, and are connected with all four wheels. The diameter of each cylinder is six inches, and the stroke fourteen inches; the diameter of the wheel is twenty-six inches. The hot water tank contains about eighty-seven gallons, and the air tanks thirty-five cubic feet.

"An experimental trip was made with this motor on the tracks of the New York Central Railroad, east of Rome. The maximum speed for one continuous mile was at the rate of twenty-four miles per hour—two and a half minutes. Not the slightest difficulty was experienced in starting or stopping the car, or regulating its speed. The deductions indicated that between the ranges of pressure—2025 and 200 pounds—the car could be run, on the same track, a distance of thirteen miles, under conditions similar to those existing at the time. The car carried twenty-six passengers; the trip was made in a snow storm, but upon a nearly level track in fine condition. If the capacity of the air-tank were doubled, or contained seventy cubic feet with the same initial pressure, the distance would be doubled."



A CAR OF THE GENERAL COMPRESSED AIR COMPANY, ROCHESTER, N. Y., U. S. A.

The advantages claimed for this system are, in general, the advantages of almost any compressed air propulsion system and are, therefore, worth quoting:—

"Motors can now be constructed to run, with a single charge of air, to the extreme distance required in any ordinary service. The system is cheaper, both in cost of plant and operation, than any other.

"The motors are independent, and are not effected, as in other systems, by the derangement of feeder or cable lines, station machinery, or by electric storms. In times of riot, or other disorder, mischievous persons cannot

obstruct the running of the cars by tampering with the source or the conductors of power.

"They require no trolley poles or wires overhead, and no cable, pipes, conduits, or other construction beneath the track.

"There can be no escape of current and no destruction of water and gas pipes by electrolysis. Their use avoids not only the unsightly poles and wires, but also the obstruction which they interpose to the use of fire apparatus, and the great expense and injury involved in tearing up and replacing pavements for the purpose of putting in underground construction. The motors are entirely under control of the motorman; they start without jerks, run at any rate of speed desired, and stop quickly and smoothly by application of air-brakes. They avoid all possibility of accidents from 'live' wires and stranded cables. They possess every advantage claimed for storage batteries, with none of their defects, and every merit desirable in a motor, while free from the objections of electric, cable and gas systems. They cannot be stalled on a railroad crossing in front of an approaching train by loss of power, as has happened with trolley lines.

"In the compressed air motor the weight is spring-supported, while in the electric motor the weight of the motor is rigidly attached to the axle. It has been found, by actual tests, in passing over an obstruction one-eighth of an inch high, that the pounding effect per ton of a rigid load at a speed of ten miles per hour was seven and one-half times as great as when the load was spring-supported, and at twenty-five miles per hour it was forty-two times as great, which explains why electric motors are so damaging to track, and why the pounding of flat wheels on such motors is so destructive. Flat wheels are produced by the excessive pressure of the trolley brake, which causes the wheel to slide upon the track.

"Electric cars require an excessive power in the motors, from the fact that the independent motors on the axle cannot be so regulated as to work synchronously. In one test the variation was so great that higher efficiency was secured with one motor than with two, and on the Intramural Railway, at Chicago, four 150 horse-power motors were used to run the train, when less than 300 horse-power would have been sufficient with a steam or air locomotive.

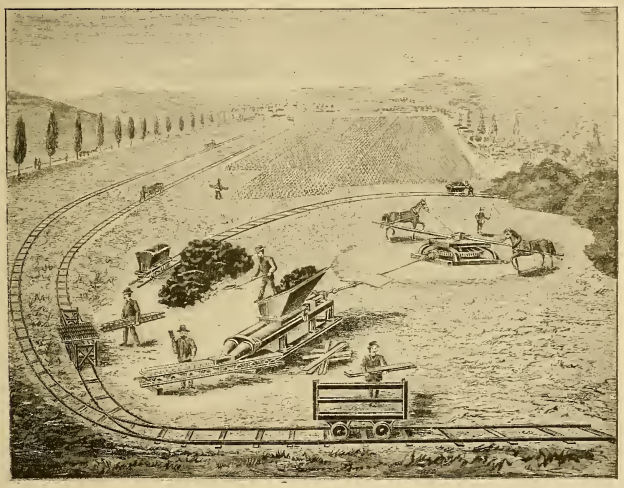
"During the last decade great improvements have been made, both in the construction of air compressors and reservoirs. Responsible manufacturers will furnish compressors capable of compressing any needed quantity of air per minute to any desired pressure at moderate prices, and guarantee performance. Riveted reservoirs, which could only stand a very moderate pressure, are now superseded by reservoirs of mild steel without joint, weld or seam, tested to double the highest working pressure without exceeding the limits of elasticity, and capable of holding the maximum charge with perfect safety. With such reservoirs, runs can be made four to five times as long as was formerly possible with the riveted cylinders, and capacity for overcoming grades with an air motor that is equal to that of a steam locomotive, being a question simply of cylinder capacity and of adhesion.

"When trailers are carried, an almost unlimited increase of reservoir capacity can be provided by putting reservoirs under the seats and floors of these cars. The adhesion of the motors is amply sufficient to ascend any ordinary grade, and the cylinders can always be large enough to furnish power to overcome the maximum resistance."

Many of the advantages claimed for this motor are self-evident and, as stated, apply as well to other compressed air motor systems, but whether they are sufficient to warrant the adoption of such a system over all others as the most desirable, economical and efficient method of street car propulsion, is a question demanding the most thorough and practical demonstration. Some former advocates of

the compressed air motor have learned that it is unwise to seek to divert sound and prudent consideration by a surplus of enthusiasm.

If street railway corporations will weigh the question of motive power thoroughly in all phases, with a careful regard alike to their own interests and to the interests of their patrons, the engineering world and the public will be satisfied that the fittest has survived, and that the system adopted, be it electric or compressed air, is the best which the age affords.



PRESSING AND DRYING PEAT.

PEAT FUEL IN GERMANY.

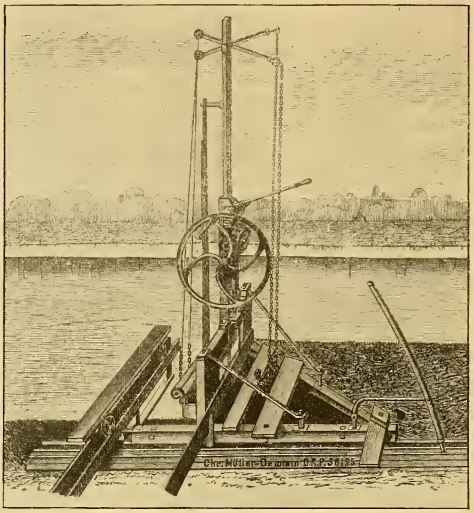
By Louis Stern.

THE increasing interest which has, in late years, been centered in cheap fuels of all kinds caused the writer, some time ago, to give careful attention to the process by which many parts of the German Empire secure their supplies of that comparatively inexpensive, but yet satisfactory, fuel—peat, or turf, and the results of his inquiries were subsequently embodied in a consular report to the United States Government. From this the appended data have been substantially taken.

Peat, or turf, is used throughout Europe generally, wherever the ordinary cost of its production is not materially increased by cost of transportation. In the large and small cities, as well as in the country districts, it is used for fuel; in fact, in many localities it is the only substance used for heating purposes. It is used likewise in industrial establishments, but its use in locomo-

tives had to be discontinued in order to prevent danger of forest and field conflagration.

According to experts on the subject, peat is composed of the following elements, the proportions varying with the respective qualities of the peat :—



A PEAT CUTTING MACHINE.

Carbon, 40 to 60 per cent.; hydrogen, 4 to 6 per cent.; nitrogen, 25 to 35 per cent.; oxygen, 1 to 6 per cent.; and ashes, 1 to 15 per cent. Of the entire superficial area of Germany, about 5 per cent. is covered by peat bogs.

Peat is the product of decayed organic matter. The main cause of the transformation of vegetable substances into peat is water of a certain composition and temperature, which, being almost still or flowing slowly in or above the earth permits of the mossy development of swamp plants and at the same time preserves the latter from total decomposition by reason of exclusion of the air.

These reasons are found to exist more particularly in the temperate zone, where the necessary variations of temperature occur, and where tracts of land are found whose impervious beds lead to continual accumulations of water, while, on the other hand, other portions of territory, with loose and penetrable beds, especially in regions inundated by the overflowing of rivers, are subjected periodically or continuously to an extraordinary saturation.

The various theories that have heretofore been advanced to account for the origin and development of peat bogs generally agree that the moors are the product of a more or less extensive decay of certain plants in a mass of vegetation, which, under favourable conditions as regards locality, climate, and moisture, is continually being renewed in one section and matured in another. The upper layer of peat, or turf, which consists for the greater part of varieties of moss, is, when broken into fragments, a loose fibrous substance—a mixture of root fibres, leaves, stems, etc. The bottom layer, known as

"pechtorf," or "specktorf" ("pitch turf"), consists of a black, compact, pitchy mass, which shrinks rapidly on being separated into small pieces. It has, when cut evenly, a smooth, wax-like surface, and is the most valuable for heating purposes.

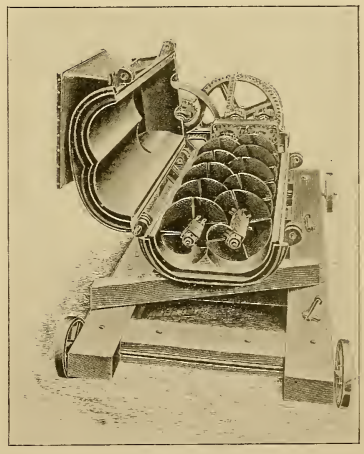
Every rational operation of peat bogs or moors must be begun by the draining of the territory to be worked, and this draining must be undertaken sufficiently in advance of the working of the peat moor itself, in order that the territory in question may attain the requisite degree of dryness. Even after this has been effected, the peat still contains water in quantity equal to from 70 to 80 per cent. of its weight, and this remaining moisture is then almost entirely removed by successive processes of drying in the air, manipulation with machinery, or subjection to artificial heat.

Until within the last few years, manual labour has been employed to work the peat bogs, but a very ingenious machine has recently been invented to take its place. This machine consists of three lancet-like knives, which, by operation of a toothed rod, cogwheel, and crank, are sunk into the peat, cutting out a square piece, which is received upon a horizontally working shelf and removed by a simple reversing of the above-mentioned contrivance. Another method consists in plowing and harrowing the bog or moor by the use of steam power and wire cables, the material for which is manufactured at Mannheim.

The process of drying the peat or turf, in so far as small moors are concerned, consists simply of exposure to the open air. When extensive territories are worked, artificial drying is resorted to, and the expense involved in the latter operation is by far the greatest incurred in the production of peat.

In Germany the following kinds of peat are known:—Cut peat, which is cut into the form of bricks by hand spades or special machines; moulded peat, which is produced by cutting the peat moss into irregular pieces, mixing it with water and then moulding it into the respective forms; machine or pressed peat, which is the result of pressing the turf, after previous separation into pieces and drying in ovens. In the category of "machine peat" is also included the so-called "ball peat" (kugeltorf)—globes of turf about 4 inches in diameter, made by passing the turf pulp through specially contrived appliances.

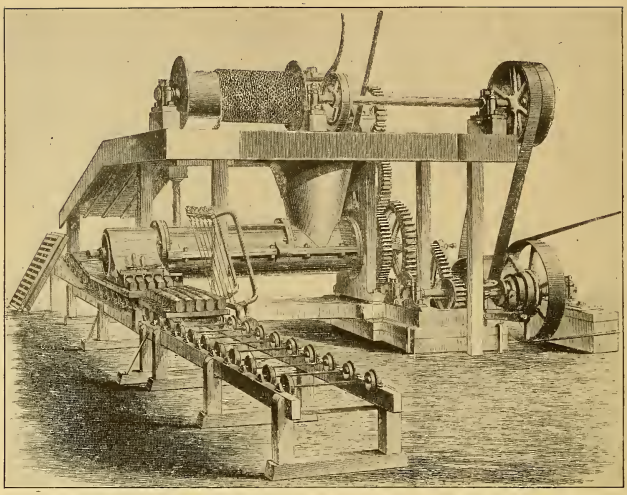
In the district of Bamberg, the moor to be worked is first freed from vegetation, leveled, plowed, and harrowed, and the loosened peat broken, so as to be exposed to the action of the air. It is then gathered by means of a kind of snow plow, brought to the separating machine, taken thence to the drying oven and the press, whence it issues in the shape of smooth, shiny, dark brown bricks. A machine in operation at one of the chief peat works in Germany, at Haspelmoor, produces, provided suitable material is used, from 10,000 to



A PEAT PRESS.

15,000 bricks in ten hours. Another machine, requiring six horse power to work it, can produce from 60,000 to 100,000 bricks a day.

It is reasonable to estimate, on an



ANOTHER FORM OF PEAT PRESS, WITH CONVEYOR ATTACHED.

average, that 100 pounds of peat are equal, in respect to the really available heating capacity, to fifty to sixty pounds of so-called "pit" coal (hard coal).

In the peat works at Haspelmoor, which are known to be a paying enterprise, the total cost of producing 100 pounds of air-dried peat amounted last year to 36 pfennigs (8.6 cents), which low figure was secured, however, mainly by reason of the comparatively low rate of wages and the inexpensive manner of living prevailing in the neighbourhood.

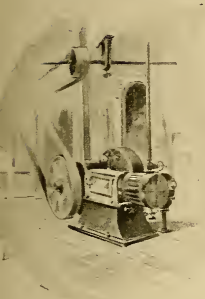
In Germany the relative cost of peat as compared with hard coal is as follows:—100 kilogrammes (kilogramme =2.2 pounds) of good Zwickau hard coal cost at the mine 1.20 to 1.62 marks (mark=1s.), while the cost of production of the same quantity of peat amounts to from 0.30 to 1.40 marks, according to quality.

Besides its use as fuel, peat is turned into account in Germany as a fertiliser and as building material, it being successfully used as a filler for vacant spaces, separating layers for waterworks, reservoirs, ice houses, etc. By means of a process patented by a tanner in Mayence, it has also been made to do services in tanneries. The waste or superfluous particles of peat, known as peat dust, have recently been brought into extensive use as a material for filling up and preserving odourless vaults, an innovation deserving strong commendation, especially in localities where the sewerage is inadequate. Hanover and Mecklenburg alone have from 140 to 150 square miles, and Bavaria has 22 square miles of peat moors.

STEAM SUPERHEATING.

By William H. Patchell.

Steam superheating is full of perplexities. Whenever it is discussed, especially before engineering societies, we have an excellent opportuuity of finding out how little we know about it, and it is on this account that brief, plain statements of test results, obtained under known sets of conditions, are of special value. They help more than any quantity of speculative talk to settle the question whether the use of superheated steam will pay. Mr. William H. Patchell's paper, recently read before the British Institutiou of Mechanical Engineers, is the latest welcome addition to the literature of the subject and it has, therefore, been reprinted here with as much detail as space limits permitted. A few of the tables had to be left out, but those that remain admirably demoustrate the benefits that the employment of superheated steam may be expected to yield.—THE EDITOR.



SUPERHEATED steam is steam of any pressure at a temperature higher than the temperature of its evaporation from water at that pressure. Saturated steam may be superheated by imparting additional heat to it at a constant pressure, during which process its volume increases. By permitting saturated steam of a given pressure to expand without doing work, superheated steam at a lower pressure may be formed. Steam cannot be superheated in the presence of the water from which it was evaporated, owing to the fact that the water takes up the heat and evaporates into further saturated steam. The corollary follows that water cannot exist in the presence of superheated steam; either the surplus heat in the steam will evaporate the water, or, if there be too little surplus heat to evaporate all the water, the steam will immediately become saturated by evaporating as much of the water as it can.

Messrs. Fairbain and Tate, Hirn and Siemens all found that saturated steam was not a true gas, and that its expansion on the application of further heat was at first much greater than that of a perfect gas. When a temperature of about 20 degrees F. above that of the saturated steam was reached, the volume increased at about the same rate as that of a perfect gas. No data appear to be yet available as to the expansion of steam with high degrees of superheat; but there is little doubt that it would be that of a perfect gas. A marked feature in the use of superheated steam is the rapid fall in the superheat from radiation, etc. The reason of this more rapid fall in temperature as compared with saturated steam seems to be that the latter owes its heat retaining properties to the water spray carried in it. It is only after this water spray has been evaporated that the steam becomes a true gas.

The greatest advantage to be gained by the use of superheated steam is in engine cylinders, and is due to the immediate absorption of the film of water on the metal surfaces by the surplus heat, thereby counteracting cylinder condensation, which is the heaviest loss in the expansive working of steam. In this connection superheated steam would appear to have an advantage over steam-jackets, inasmuch as the heat is applied exactly where it is wanted, and during the period that it is wanted, that is, up to the point of cut-off; whereas a steam jacket wastes a considerable part of its heat and time in warming up the exhaust.

That economy attends the use of superheated steam in engine cylinders has been known at least since 1828, when Richard Trevithick reported on the engines at Binner Downs mine in Cornwall.* The engineer of the mine, Cap-

*Life of Richard Trevithick, vol. 2, pages 315 and 313-4.

tain Gregor, wishing to rival the record of a neighbouring mine where the cylinders had been cleaned in sawdust, built in his cylinders and steam-pipes with brickwork, making a fire-grate underneath them and flues around. The results were unexpected, and the duty of the engine was raised from forty-one to sixty-three million foot-pounds per bushel (84 pounds) of coal.

Trevithick tested the 70 inch cylinder engine, which, when 5 bushels of coal were burned in 24 hours under the cylinder, took 67 bushels under the boiler; when no coal was burned under the cylinder, 108 bushels of coal were used under the boiler for the same work, showing a saving of one-third of the coal by superheating. The steam pressure was 45 lbs. per square inch, and the strokes eight per minute. With the cylinder fires on, 13 gallons of injection condensing water were used per stroke, and heated from 70 degrees to 104 degrees; without the cylinder fires, 15½ gallons of condensing water were used per stroke, and heated from 70 degrees to 112 degrees. Trevithick followed this up by inventing in 1832 a tubular boiler, combined with a superheater between the boiler and the engine cylinder; he also jacketed the cylinder with the waste gases from the furnace. In Fig. 1 is shown the arrangement, copied from his patent No. 6308 of 1832. The external series of vertical pipes, connected top and bottom to a hollow ring, constitute the boiler; the superheating pipes inside it are formed like inverted siphons, so as to avoid jointing at the lower end next the fire. Trevithick had been combating cylinder condensation for thirty years before this date, having, in 1802, in conjunction with Vivian, constructed a non-condensing engine, the cylinder of which was placed inside the boiler—a plan followed for many years with much success in agricultural portable engines by Messrs. Hornsby of Granham.

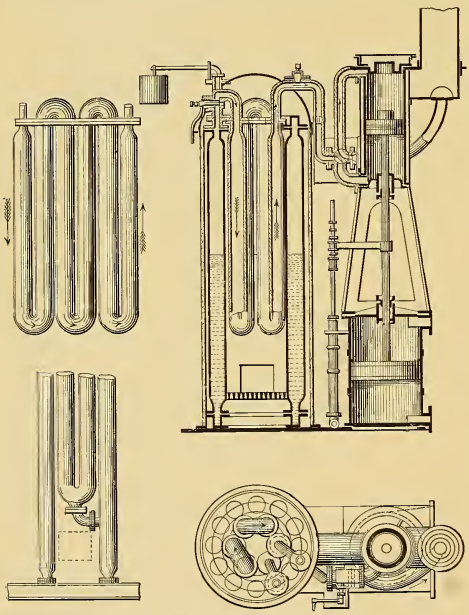


FIG. 1. TREVITHICK'S SUPERHEATER.

Owing, doubtless, to the difficulty in controlling the temperature imparted to the steam, superheating made but little headway till 1850, when it came to the front again. Many plans were then proposed for superheaters and steam driers in various forms, both attached to boiler flues and separately fired. Asbestos packings and brass bushes with plumbago plugs were then introduced to meet the demand for steam-tight glands under superheated steam.

Some results then obtained were reported to this institution by Mr. John Penn in 1859, followed by Mr. John N. Ryder in 1860. Mr. Penn described the apparatus employed by him in the *Valetta* steamer of the Peninsular and Oriental Co., with engines of 260 nominal horse-power, where the saving

in fuel due to superheating was 20 per cent. The superheater consisted of two horizontal faggots, each of forty-four 2-inch tubes, placed in the smoke-box. The tubes were fixed into three wrought-iron boxes, welded up at the corners and closed with a flanged joint. The steam from the boiler passed into the centre box, thence through the tubes into the end boxes on its way to the engines, taking up heat from the escaping gases which would have been otherwise wasted. The proportions of the apparatus were given by Mr. Penn as 2¾ square feet of superheating surface per nominal horse-power; the boilers had a heating surface of 19 square feet per nominal horse-power. The steam pressure was 20 lbs. per square inch, and the amount of superheat about 100 degrees F.

Mr. John N. Ryder dealt with Messrs. Parson and Pilgrim's apparatus as fitted on marine boilers, and also Mr. David Patridge's superheater. The Parson and Pilgrim apparatus consisted of two horse-shoe pipes, fixed over the fire-grate in the internal flue of the boiler. Tests on the steamers *Osprey* and *Swift* showed a saving over saturated steam of 30 to 40 per cent. in fuel; and on H. M. steam tug *Bustler* a mean of thirty-seven trials with a pressure of 8½ lbs. and a temperature of 380 degrees in the cylinders, which is 144 degrees of superheat, gave 25 per cent. economy.

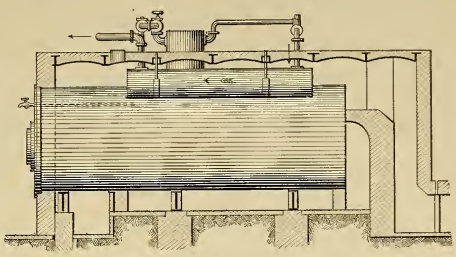


FIG. 2. GEHRE'S SUPERHEATER.

Mr. Patridge's apparatus was a cylinder filled with tubes, placed vertically in the uptake. The gases passed through the tubes, and the steam around them; the working temperature was from 360 degrees to 390 degrees. H. M. steamship *Dee* was fitted and tested for several months by the Admiralty, when an economy of fuel of from 20 to 25 per cent. was obtained. An aggregate of about 5000 horse-power was stated to be then working

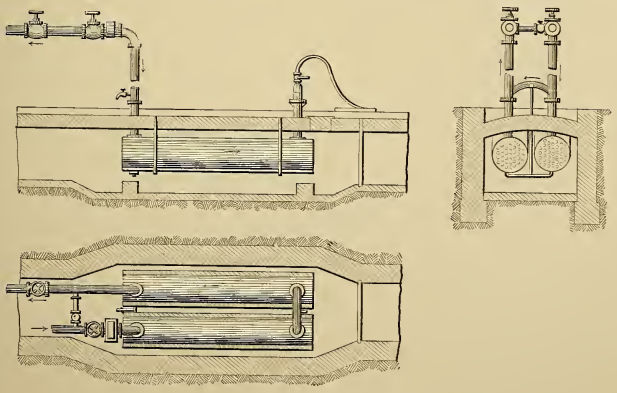


FIG. 3. DETAILS OF GEHRE'S APPARATUS.

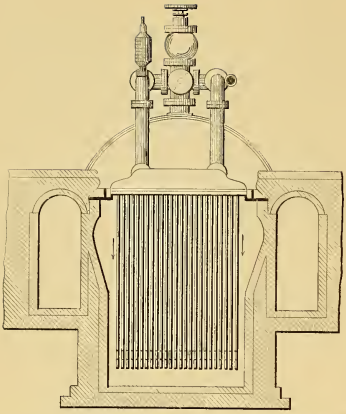


FIG. 4. HICK, HARGREAVES & CO.'S SUPERHEATER.

with this apparatus. Following closely on Mr. Ryder's paper was one read by the Hon. John Wethered, of the United States, at the Institution of Civil Engineers (Proceedings 1860, vol. xix), wherein he animadverted on the futility of the common kinds of superheater, and strongly advised mixed or combined steam, which he claimed to have introduced from America four years previously.

If superheating was so common and of such manifest importance and efficiency in the saving of fuel some forty years ago, the question arises, why was it given up, and what factors that led to its abandonment have been eliminated in modern practice?

Trouble was formerly experienced at the valve faces and in the cylinders from the decomposition and destruction, at the high temperatures of superheated steam, of the tallow and the low-class lubricants then in vogue. This trouble was twofold —the cutting and excessive wear in the absence of lubrication; and the pitting caused by the fatty acids in the lubricant. On this score, however, no trouble need now be anticipated at any degree of superheat likely to be attained, where good hydro-carbon oils are used. Gas engines run in regular working with a cylinder temperature in the neighbourhood of 2000 degrees Fahrenheit, lubricated with good oil; and with ordinary care and attention instances of cutting are not frequent. The common use of metallic packings for glands, and of piston valves in place of flat valves, has removed another serious obstacle. In this connection it will be well to note that pistons and valves which show little leakage when used with saturated steam may show considerable leakage with dry steam, probably owing to the film of water on the metal improving the fit when saturated steam is used.

Much of the trouble that has been attributed to the effects of superheat, in respect of cut cylinders and valve faces, has, in the author's opinion, been due in reality to the effect of alternate superheat and water in the steam, owing to want of proper control of the superheaters. A superheater may give a high degree of superheat when the fires are in good order, and at another time may

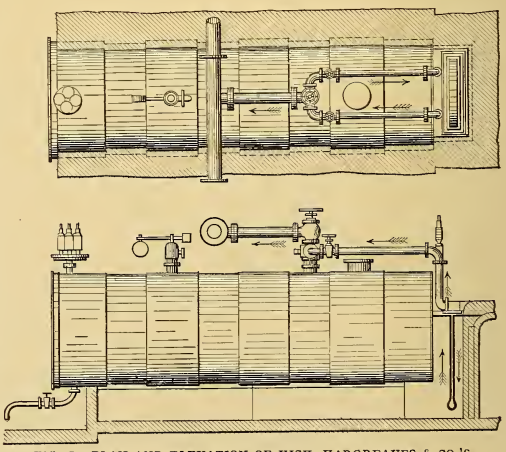


FIG. 5. PLAN AND ELEVATION OF HICK, HARGREAVES & CO.'S SUPERHEATER.

even act as a condenser. The effect of this alternation demands much closer attention than it has at present received. A somewhat parallel case is the behaviour of a good hydro-carbon cylinder-oil, which in one engine, with normal dry steam, leaves no deposit; whereas in a sister engine, at the same steam-pressure, with wet steam, a heavy deposit is formed from the same oil.

An instance of a cut cylinder which had to be re-bored has lately come under the author's notice, where it appears from the evidence that the trouble is not to be attributed either to the degree of superheat in itself, or to the lubricant, or to neglect on the part of the engineer in charge, but to the alternate effects of superheated and wet steam in the cylinder.

The majority of the old troubles were met with in the engines; but the superheaters themselves do not appear to have been always above reproach. When endeavouring to trace failures to faults in pipes or joints, the author has sometimes found superheaters which were fixed with a by-pass for the steam, but none for the gases. The boilers were then worked occasionally with the steam shut off the superheater; and it is not surprising that the latter deteriorated rapidly, its position being eminently unsuitable for a combination of boxes, pipes, and expanded tube-joints.

Concurrently with the increased efficiencies gained in late years in both boilers and engines, competition has also increased; and with it has arisen the continual cry for cheaper power, cheaper transport, cheaper means of production. The result is that engineers cannot afford to dismiss without careful examination the claims of any plan, the adoption of which may diminish their consumption of fuel. It is this fact which has again brought superheating to the front, and has made it the subject of close enquiry in many quarters. Several kinds of superheater are now in more or less extensive use; but only one of them is a radical departure from those of forty years ago. Any change in the others is rather in manufacture than in design; and their parentage can be traced by their strong family likeness.

Gehre's Superheater.

This is in extensive use on the Continent, and has been introduced into England by Messrs. B. Donkin & Co., of Bermondsey. It is shown in Figs. 2 and 3, and may be either fitted

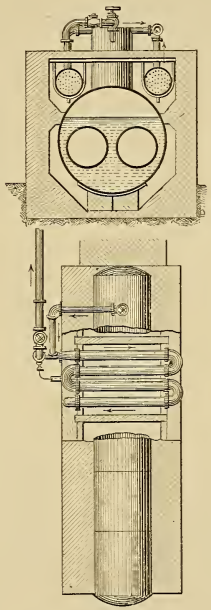


FIG. 6. THE MCPHAIL & SIMPSON APPARATUS.

in the boiler flue or separately fired. Some of these superheaters have been fixed in England, but unfortunately they have not been tested. Mr. Bryan Donkin kindly gave the author a copy of a test made in Germany, of eight hours' duration, on a water-tube boiler with and without the superheater, Table 1. The heating surface of the boiler was 861 square feet, and of the superheater 646 square feet. The superheater was placed directly behind the boiler in a special flue.

Table 1.—Boiler Test With and Without Gehre's Superheater.

	With.	Without.
Total coal used during trial	1,550	1,940 lbs.
Total water used during trial	15,400	15,100 lbs.
Temperature of feed water	205°	201° F.
Superheat in steam	40°	— F.
Temperature of furnace gases before superheater	600°	600° F.
Temperature of furnace gases after superheater	510°	— F.
Water evaporated per pound of coal	9.99	7.82 lbs.
Water evaporated per square foot of heating surface per hour	2.23	2.20 lbs.
Pressure of steam per square inch above atmosphere	110–114	110–114 lbs.
More steam used	—	5 p. ct.
Less coal used	34	— p. ct.
Less work on engine	—	7 p. ct.

HICK, HARGREAVES & CO.'S SUPERHEATER.

By the courtesy of the makers, the author has been favoured with the following particulars and tests (Table 2) of their superheating apparatus in a mill at Bolton. As shown in Figs. 4 and 5, the apparatus consists of a nest of U tubes, bent to a large radius at the bottom, which are placed at the back of a Lancashire boiler where the hottest gases from the flues impinge upon them. The tubes are suspended from a tube-plate, forming the bottom of a box, in which they are fixed by being expanded in the usual manner. The box is divided down the middle by a vertical diaphragm, so that the saturated steam, entering at one side, passes down and up through the tubes, and leaves superheated at the other side. A by-pass valve is arranged to regulate the flow of steam through the superheater, because only a portion of the steam from the boiler is intended to be superheated. Main valves are also provided, so that the superheater can be disconnected for examination, or even taken out entirely, without interrupting the working of the boiler. The Lancashire boiler to which the superheater is applied is 8½ feet in diameter and 30 feet long, with two flues 3¼ feet in diameter, having nine circulating tubes in each. The grate surface is 39 square feet; the heating surface in the boiler is 1195 square feet, and in the superheater 120 square feet. The area of passage through the superheating pipes is 22 square inches. The boiler pressure is 100 pounds per square inch above atmosphere. In the tests a portion only of the steam was superheated. The steam pipes to and from the superheater are 3½ inches diameter, and are provided with valves, which were kept full open. The main stop-valve on the boiler is 8 inches diameter, and was kept only 5-16ths inch open. The steam was taken to the superheater from underneath this valve, and the return pipe from the superheater was conducted direct to the main range of steam pipe supplying the engine. The temperature of the gases was not taken. The engine is a horizontal tandem compound, fitted with Corliss valve-gear; cylinders 18 1-16 and 36 1-16 inches diameter by 4 feet stroke. Each of the tests was of 7½ hours' duration.

The much easier working of the boiler for the same indicated horse-power at the engine is to be noted. During the tests of March 20-21 and March 26-27 the load was practically identical. In the former tests with superheating the rate of coal consumption was 18.8 pounds per square foot of grate per hour, whereas in the latter tests without superheating the combustion went up

Table 2.—Boiler Tests With and Without Hick, Hargreaves & Co.'s Superheater.

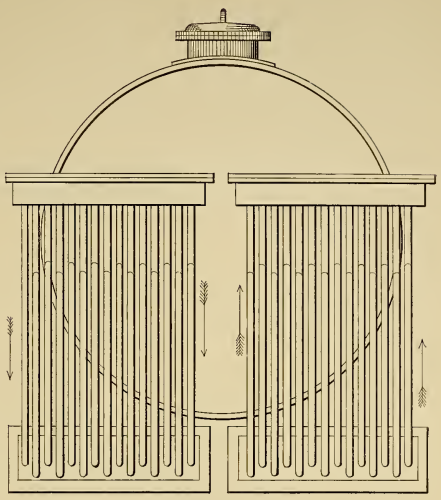
Dates of Tests.	Number of Tests With or Without Superheater.	Mean Load.	Water Evaporated per Hour.	Coal Burnt per Hour.	Water Evaporated per Lb. of Coal.	Water Evaporated per I. H. P. per Hour.	Coal Burnt per I. H. P. per Hour.	Degrees of Superheat.
1895.		I. H. P.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Fahr.
February 19–20	2 Without	303.55	5379.3	837.6	6.42	17.7	2.75	--
March 1–2	2 With	290.5	4706.3	667.2	7.06	16.2	2.29	42°
March 5–6–7–8	4 With	298.06	4778.5	676.5	7.06	16.0	2.28	42°
March 20–21	2 With	311.2	5141.1	734.7	7.00	15.5	2.35	55°
March 26–27	2 Without	311.8	5402.1	914.0	6.00	17.6	2.92	--
Means	Without	307.67	5435.7	875.8	6.21	17.6	2.84	--
	With	299.45	4848.6	688.7	7.09	15.9	2.30	45.2°

Economy in water per I. H. P. per hour, 9.6 per cent. with superheating.
" " coal " " " " 19 " " " "

to 23.4 lbs. of coal per square foot of grate per hour. Where there is a low and uncertain chimney draft, this slower combustion alone would tend to much steadier and more economical steaming, and would more than counterbalance any obstruction in the flues, caused by the superheating pipes, which appears to be more imaginary than real.

McPhail and Simpson's Superheater.

This apparatus is the invention of Mr. Hugh McPhail, and is manufactured in Wakefield by McPhail and Simpson's Dry Steam Patents Co. It consists of two parts,—the superheater proper, and the steam generator of radiating tubes, which distinguishes it from all other plans. As applied to a Lancashire boiler, Figs. 6, 7 and 8, there are two nests of vertical steel tubes, expanded at top and bottom into cast-steel boxes, or "headers," as they are called in water-tube boilers; these nests are placed preferably at the back end of the internal flues of the Lancashire boiler, in the down-take, where the furnace gases impinge on them and pass between them. One of the top boxes is connected to the usual anti-priming pipe in the boiler, and the corresponding bottom box is connected to a block, which passes into the bottom of the boiler, and from which a copper pipe runs along the bottom of the boiler under the internal flues to the front end, and thence back again to the rear, where it passes out of the boiler and into the other bottom box. The second top box is connected to another copper pipe, which runs along the boiler over the internal flues, just below the water-line, and ends at the main steam stop-valve.



ENLARGED END VIEW.

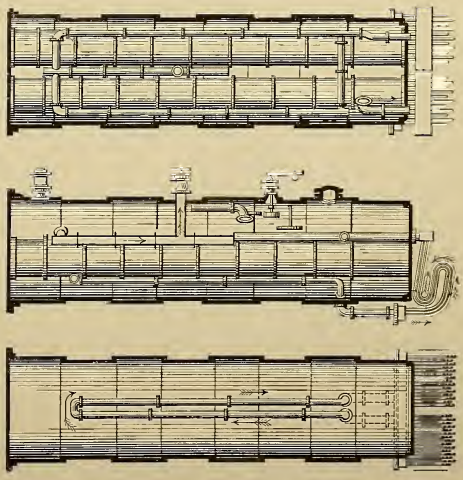


FIG 7. THE MC PHAIL & SIMPSON APPARATUS, APPLIED TO A LANCASHIRE BOILER.

The course of the steam is from the anti-priming pipe to the first top box, then down through the superheating tubes to the first bottom box, whence it enters the boiler, and, passing through the lower copper pipe, gives up part of its superheat to the surrounding water before leaving the boiler and entering the second bottom box. It is then further superheated in passing up through the second nest of tubes; and thence, passing through the second top box into the upper copper pipe in the boiler, it again parts with some of its superheat before finally leaving the boiler at the steam stop-valve.

The complete apparatus thus consists of two external superheaters and two internal radiators; and the final degree of superheat depends upon the proportion of the superheating tubes to the radiating pipes. The function of these radiating pipes is most important, as they give off to the water in the boiler the superheat which might be dangerous in the engines at times of heavy firing; and, when the fires are green after cleaning and the flue gases low in temperature, they prevent any possibility of the superheater becoming a condenser. They thus tend to keep regular the amount of superheat in the steam as it leaves the boiler. It will be evident, therefore, that this superheater may be arranged either for improving the evaporative efficiency of a boiler and at the same time giving dry steam at the engine, or for the steam to leave the boiler highly superheated.

In its complete form this superheater has been tested and fully reported upon by several engineers in England, among whom may be mentioned Messrs. Crosland and Michael Longridge.

This type of superheater was adopted by the author in 1893 at the Maiden Lane station of the Charing Cross and Strand Electricity Supply Corporation, but had to be considerably modified to suit the Babcock and Wilcox water tube boiler, as it was found possible to put only one set of superheating tubes in the limited space between the top of the water tubes and the underside of the drum, and only one set of radiating pipes in the drum; so that the arrangement represents only one-half of the complete apparatus as applied to a Lancashire or double-flued boiler. The arrangement is shown in Figs. 9 and 10. The saturated steam is taken from the anti-priming pipe to the upper box of

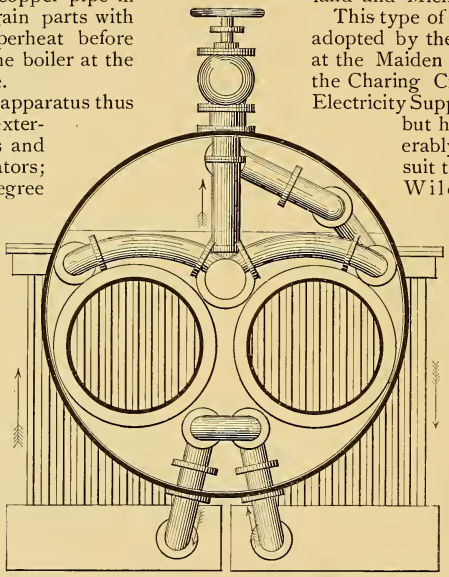
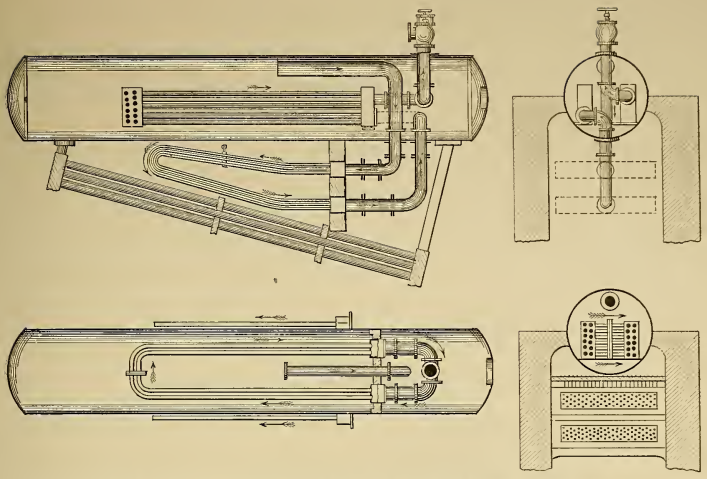


FIG. 8. A DETAIL OF THE MC PHAIL & SIMPSON SUPERHEATER.



FIGS. 9 AND 10. MC PHAIL & SIMPSON'S SUPERHEATER APPLIED TO A BABCOCK & WILCOX BOILER.

the superheater, whence it passes down through the superheating tubes to the lower box, thence up into the radiating pipes in the drum, and through these to the steam stop-valve. The principal dimensions of the Babcock and Wilcox boiler are :— $9 \times 9 = 81$ tubes, 18 feet long and 4 inches diameter ; total heating surface about 1827 square feet ; drum 23½ feet long and 4 feet diameter ; width of fire-grate 5 feet 6 inches ; total grate surface 34.4 square feet. The principal dimensions of the superheater are :— 75 superheating tubes of 1 inch diameter, heating surface 355 square feet ; 12 radiating pipes of 2 inches diameter, heating surface 174 square feet ; area through superheating tubes 58.9 square inches, through radiating pipes 37.7 square inches, and through steam stop-valve 28.27 square inches.

Complete tests of one boiler were made by Professor Kennedy, before and after the superheating apparatus was fixed, and the principal results are given in Table 3 on the next page. The dynamos are Edison-Hopkinson continuous-current shunt-wound, driven by Willans engines.

The great increase in the capacity of the boiler will be noted in line 8 ; the steaming was much easier and steadier, and at the same time the efficiency of the boiler improved from 68.4 per cent. to 74.9 per cent. (line 29), and this with cold feed. Practically the whole of the superheat was lost in the range of steam-pipes between the boiler and engine. The slight difference in water used per kilo-watt hour may be accounted for by the engine not being in such good order in the second test as in the first. It had been thoroughly overhauled immediately before the June trial, and had been in daily use from that date until the October trial, so that both valve and piston-rings would be somewhat slacker in October than in June. The same cause would affect the coal consumption, which nevertheless shows a saving of 13.5 per cent.

The increased capacity and ease in working of the boiler have been as marked in its subsequent use with the superheating apparatus ; in regular work it is evaporating about 50 per cent. more than heretofore. At first, the author had some misgivings as to incrustation forming in the superheating

Table 3.—Boiler Tests Without and With McPhail & Simpson's Superheater.

			Without.	With.
1	Date of trial	1893	June 20	Oct. 17
2	Duration of trial, hours and minutes		8-15	8-31
3	Indicated horse-power of engines working at full load	I. H. P.	135	135+80
4	Full output of dynamos, ampères × volts		$75ca \times 105v$	$\left.\begin{matrix} 750a \times 105v \\ 450a \times 105v \end{matrix}\right\}$
5	Coal burnt, total	lbs.	3,229	4,528
6	" per hour	lbs.	389	532
7	Water pumped into boiler, total	lbs.	28,000	43,655
8	" " " per hour	lbs.	3,457	5,125
9	Mean electrical horse-power	E. H. P.	82.15	129.2
10	Total kilo-watt hours (units)		686.4	824.2
11	Mean kilo-watts		61.3	97.0
12	Boiler pressure above atm., per sq. inch	lbs.	131.3	140.3
13	Mean temperature of steam on leaving boiler	Fahr.	355°	377.1°
14	Mean temperature of saturation at boiler pressure	Fahr.	355°	361.0°
15	Mean temperature of steam in engine-room steam-pipes	Fahr.		365.1°
16	Mean temperature of saturation at probable pressure in engine-room steam pipes	Fahr.		358.3°
17	Mean temperature of feed-water	Fahr.	80.4°	79.76°
18	Calorific value of 1 lb. of coal	Th. U.	14,840	14,790
19	Equivalent evaporation per lb. of coal	lbs.	15.36	15.31
20	Carbon value of coal per lb	lbs.	1.023	1.020
21	Actual water evaporated per lb. of coal	lbs.	8.89	9 65
22	Evaporation per lb. of coal from and at 212°	lbs.	10.50	11.47
23	Evaporation per lb. of carbon value	lbs.	1.030	1.122
24	Coal burnt per hour per sq. foot of grate	lbs.	11.3	15.5
25	" " " E. H. P	lbs.	4.74	4 12
26	Water per hour per E. H. P	lbs.	42.1	39.7
27	Coal per kilo-watt hour	lbs.	6.35	5.5
28	Water " "	lbs.	56.4	52.8
29	Efficiency of boiler, 100 × line 22 ÷ line 19	per cent.	68.4	74.9
30	Temperature of gases leaving boiler	Fahr.	309°	376°
31	Mean chimney draught, inch of water	Inch.	0.3	0.4

tubes from the priming water ; but from examining them closely on several occasions after a run of 4000 hours and more, and finding them perfectly clean, he is satisfied on this point. The top box, by its increase in area over the steam-pipe, gives a period of comparative rest in the flow of the steam, and acts as an efficient separator for the water or scum carried over. A steam trap, fitted to the box, discharges any such accumulation regularly, thus preventing its being carried into the superheating tubes. The bottom box is also fitted with a trap to intercept any leakage from the steam stop-valve when the boiler is shut in.

The first apparatus proved so satisfactory that a second was applied to the companion boiler in 1894, when the effect of the superheated steam in the pipes began to be marked by a decrease in the discharge from the drains and in the leakage from joints. There are altogether seven boilers, of which five or six are in general use on a common steam-main. The figures in Table 4 on page 126 show this effect clearly.

The duty of the boilers having been increased to the above extent, and the priming difficulty being quite overcome, the only limit to the evaporation was the chimney draught. As the two boilers were fitted with an independent flue and chimney, they lent themselves readily to an experiment in this direction. Having considered several schemes of forced and induced draught as an auxiliary, the author finally decided on puting a fan in the flue at the back of the boilers. As there was no space available for any form of economiser between the boilers and the fan, no attempt could be made to diminish the loss from heat in the waste gases. The gain sought for was in the direction of increasing the capacity of the existing boilers, so as to render steaming independent of the natural effects of foggy or heavy weather, and, by working the boilers at a higher rate, to diminish the proportion of radiation losses, which are practically constant at all loads.

The fan selected is a 72-inch single-inlet, made by Messrs. G. E. Belliss and Co., and driven direct by one of their tandem compound self-lubricating engines, having cylinders 3½ and 6 inches diameter and 4½ inches stroke, working at 150 lbs. boiler pressure and running at 300 revolutions per minute. The engine and fan were put in somewhat large for the estimated work, in order to secure slow speed and quiet

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running, with the result that within a few feet of the fan it is impossible to tell by the sound whether it is running or not; this is a marked improvement on many fan engines. A draught in the flue at the fan inlet equal to a 2-inch water-gauge has been easily maintained. The usual method of working is to operate the boilers on natural draught at times of light load; and down day after day for some weeks, and then raised again with the induced draught; and there was an entire absence of any signs of irregularity or trouble.

When the boiler is steaming freely, an iron bar, inserted through the brickwork to a point near the ends of the tubes, soon becomes red-hot; and the temperature, as taken by a platinum-coil

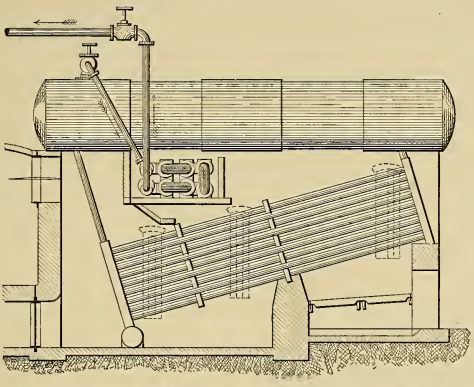


FIG. 11. THE SCHWOERER SUPERHEATER APPLIED TO A BABCOCK & WILCOX BOILER

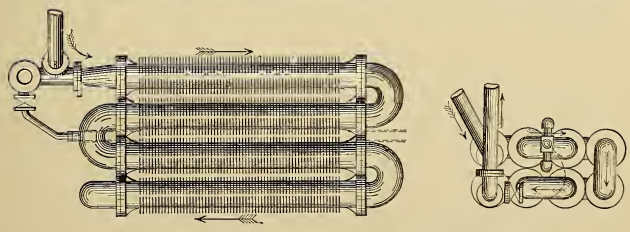


FIG. 12. DETAILS OF THE SCHWOERER SUPERHEATER.

then, as the load increases, to start the fan, close the by-pass in the flue, and work steadily at 1-inch water-gauge. With this draught the superheater tubes are continually bathed in incandescent gases, but not the slightest trouble has been experienced with them. In order to test the thorough reliability of the tubes, and in view of the fact that trouble was most likely to arise, if at all, when getting up steam, one of the boilers was shut in, and the steam let

pyrometer at this point, is about 900 degrees F. At this temperature it appears to be of little importance whether the cooling agent is water or steam, so long as the circulation is kept up. This circumstance is most interesting in view of Mr. Durston's Devonport's experiments, reported in his presidential address to the Institute of Marine Engineers,* as to the permissible limit of temperature in a tube or tube-

* *Engineering*, October 4, 1895.

Table 4.—Steam Tests Without and With McPhail & Simpson's Superheaters.

Without and With Superheaters.	Without.		With.		
Boiler pressure, absolute, lbs. per square inch	166	168	157	162	162
Corresponding temperature of saturated steam, Fahr	366.5	367.0	362.0	361 5	364.5
Temperature in main steam-pipe in engine-room, Fahr	359	361	371	375	373
Fall or rise in temperature of steam, degrees Fahr	—7.5	—6 0	+9.0	+10.5	+8.5

plate, which he places at about 750 degrees F.; and in view also of the grave doubts that are frequently expressed as to the safety of steel tubes exposed to furnace temperatures without a perfect circulation of water on the other side of the metal. What temperature the tubes actually reach, the author is unable to state; but the steam coming out of them is at over 600 degrees. The tube-plates would be lower

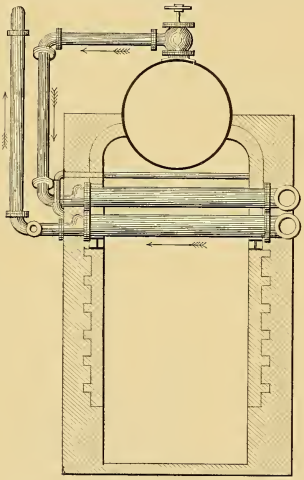


FIG. 13. THE SCHWOERER SUPERHEATER. END VIEW AND SECTION OF FIG. 11.

in temperature than the outer ends of the tubes, because the gases are drawn downwards and away from the plates by the draught. No trace of leakage at any one of the tube ends has yet appeared.

A further test of the boiler with the induced draught was made on January 2nd, 1896. It was not possible to shut off part of the steam ring-main, and to use the steam on certain steam dynamos only, measuring the electrical output from them, as had been done in the two former tests; an evaporative test only was therefore arranged for. The stop-valve temperature was measured about five feet from the stop-valve at the boiler, on a branch pipe about ten feet long, connecting the boiler with the main ring. A mercury thermometer in a mercury cup, let into the steam-pipe, was used in this position. Being anxious to get the temperature of the steam between the superheater and the radiating pipes in the drum, the author had tried mercury thermometers, which failed. The difficulties due to the high pressure and temperature were successfully overcome, however, by Mr. F. W. Burstall, to whose ingenuity and kindness in co-operation the author is indebted in this matter. With a temperature of 1058 degrees around the superheating tubes, steam entering at 362 degrees left them at 650 degrees, and after passing through the radiating pipes in the drum, left the boiler at 403 degrees F. The principal results are given in Table 5, the boiler being fired with Welsh steam coal.

Table 5.—Test of Babcock & Wilcox Boiler Fitted with McPhail & Simpson's Superheater.

Date of trial	1896	Jan. 2.
Duration of trial	hours	8
Coal burned, total	lbs.	8,050
" per hour	lbs.	1,006.25
Ash and clinker, dry	lbs.	476
Water evaporated, total	lbs.	66,350
" " per hour	lbs.	8,293.75
Boiler pressure above atm. per square inch	lbs.	148.3
Temperature corresponding with pressure	Fahr.	365°
Mean temperature of steam at stop-valve	Fahr.	396.6°
Degrees of superheat	Fahr.	31.6°
Mean temperature of feed-water	Fahr.	48°
Actual water evaporated per lb. of coal	lbs.	8.24
Actual water evaporated per lb. of combustible	lbs.	8.76
Water evaporated per lb. of coal from and at 212° F	lbs.	10.16
Water evaporated per lb. of combustible at 212° F	lbs.	10.80
Coal burned per sq. ft. of grate per hour	lbs.	29.3
Water evaporated per sq. ft. of heating surface per hour	lbs.	4.37
Temperature of gases leaving boiler	Fahr.	655°
Mean chimney draught, inches of water	Inch	1.11

Schwoerer's Superheater.

The superheater illustrated in Figs. 11 to 13 is the invention of Mr. Emile Schwoerer of Colmar, Alsace, who was for some time private secretary to the late Mr. G. A. Hirn. It was Mr. Hirn who first took up superheating seriously; and it is due to his energy that so much has been done with it in practical working in Alsace. Mr. Schwoerer's improvements were in the direction of reducing the space occupied by the apparatus; and he attained this end by employing a coil of pipes with gills on them both inside and outside, thus getting large surfaces in a small bulk. Regulation of the superheat by deflecting the hot gases away from the tubes, rather than by varying the proportion of the total steam passing through the tubes, is due to Mr. Schwoerer, though this regulation does not appear to have been generally carried out.

An application of the Schwoerer superheater has been made by Messrs. James Simpson & Co. to a Babcock & Wilcox water-tube boiler at the Grand Junction Water-Works, Kew. The arrangement is shown in Figs. 11 to 13. The boiler is of the same size as those fitted by the author with McPhail's apparatus at Maiden Lane. Full details of the trials unfortunately cannot be obtained, but the saving effected is satisfactory. Tests were conducted by Mr. Osbert Chadwick before and after the superheater was fixed, with the results given in Table 6 on the following page.

A test was also conducted by Mr. Goodman, the superintending engineer at the pumping station, under ordinary working conditions from December 8, 1894, to January 5, 1895, the engine and boiler being kept continually at work. The fuel used was 86.98 per cent. anthracite peas and 13.02 per cent. breeze, the draught being assisted by a Meldrum blower. The results then obtained were :—

Duration of trial	723½ hours
Feed-water per hour	3,223 lbs.
Fuel per hour	471 lbs.
Steam per pump horse-power per hour	17.74 lbs.
Fuel per pump horse-power per hour	2.58 lbs.
Mean superheat	121° Fahr.

These results showed a saving of about 15 per cent. on what had been obtained before the Schwoerer superheater was fixed.

This type of superheater is also made by Messrs. Fraser & Chalmers, Erith, who have one in constant use at their works.

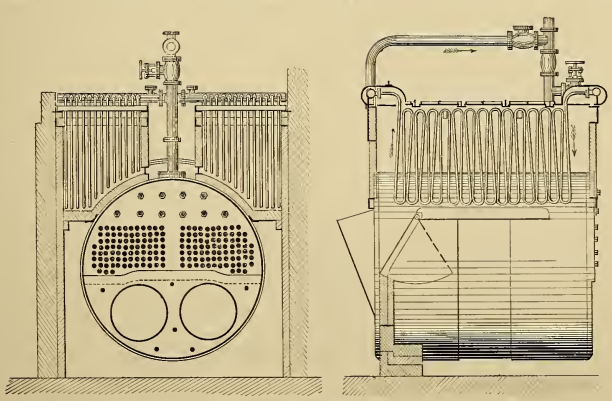


FIG. 14. THE SINCLAIR SUPERHEATER.

Sinclair's Superheater.

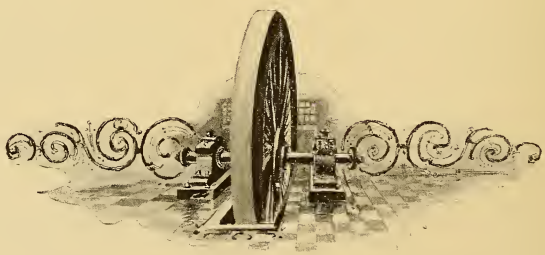
Another form of superheater is shown in Fig. 14, which is due to Mr. George Sinclair, of Leith. There is here a departure from the usual method of securing the tubes, which in this apparatus are flanged and bolted to the cross in-

let and outlet pipes, instead of being expanded into them. In such positions an expanded joint is generally considered desirable ; but here the joints are removed from the action of the hot gases, and a bolted joint gives much greater facilities for removing a tube in order to examine or clean it. In Fig. 14 the apparatus is shown in conjunction with a marine dry-back boiler, as fitted by Professor Kennedy at the Edinburgh Electric Lighting Station. The arrangement is very compact, and should prove highly economical. The hot gases from the smoke-box at the front are led to the back over the top of the boiler, passing among the superheating tubes; thence down the sides of the boiler to the centre flue underneath it.

It is much to be regretted that so little has been done as yet with superheated steam at the engine. In nearly every instance the superheat appears to be gone, if not at the steam-chest, at any rate immediately on admission to the cylinder. But even under these circumstances the advantage of superheating is manifest from many of the tests given above ; and it must be recognised that, although the steam may be cooled down again to the temperature corresponding with the pressure, it is still dry steam, and is a better working gas than the saturated solution of water-dust supplied by an ordinary boiler. The desirable amount of superheat has been generally considered to be the equivalent of the heat lost by initial condensation ; but this does not obtain in practice. The amount of heat lost in initial condensation is generally from twenty to twenty-five per cent. of the total heat of the steam above boiling point. Tests with superheated steam show a saving of twenty per cent. with only five per cent. extra heat in the steam.

Table 6.—Boiler Tests Without and With Schwoerer's Superheater.

Date	Jan. 21, 93	Dec. 20, 93	Feb. 22, 94	Mar. 13, 94
Degrees of Superheat, Fahr	0°	57.7°	109.5°	57.0°
Steam per pump H. P. per hour, lbs	20.98	19.71	18.75	19.48
Saving effected, per cent		6.05	10.63	6.75



THE VALUE OF ENGINEERING PUBLICATIONS IN LAWSUITS.

By Walter G. Berg.

IN CASSIER'S MAGAZINE for March, 1896, there appeared a valuable article on "The Expert Engineer," in which the prominent characteristics and duties of the ideal consulting engineer were discussed, not only in his relations towards clients in the designing and carrying out of engineering work, but also in the matter of furnishing "expert testimony" in court proceedings.

The trials and tribulations, as also the importance and necessity of the "consulting engineer," as a distinct species of the genus *H. sapiens ingen.*, are brought out very effectively by arguments and statements, presented from the standpoint of a professional consulting engineer, and are illustrated by numerous anecdotes, presumably borrowed from the author's personal experience or by hearsay from that of his confrères.

No direct mention is made, however, of the great value of engineering publications to the profession, which is one of the most important elements entering into the successful prosecution of any engineering work, and especially into the general and analytical work required of the "expert engineer" drawn in for professional consultation, or retained in some lawsuit.

Formerly a professional man's library consisted of a few standard general compendiums and a miscellaneous collection of tables in the form of a pocket-book or *vade mecum*.

During the last twenty-five years engineering and technical literature has been steadily increasing until to-day there is hardly a specialty in any line of engineering, architecture, mechanics or the industrial arts that is not represented by special treatises and periodicals. In addition, the large number of associations formed for the purpose of disseminating special knowledge in each particular line add their quota to the mass of published data.

The rush of our times precludes the possibility of an engineer relying solely on his college text books, supplemented by personal observation and experience. This method would not give the quick tangible result that is the aim of every young man to-day. Hence, the value of consulting the works of specialists, and more particularly the technical press, so as to obtain in condensed form and with the least loss of time the views and practical experience of others. The men who keep abreast of the times are the ones to succeed in the long run. The technical periodicals are just as much a necessity to the progressive professional man as the daily press is for the enlightenment of the general reader.

It is usually assumed that the acquisition of a professional library by young engineers is an impossibility with the means at their command, and that the busy engineer has not the opportunity to visit public libraries, which are generally open only during working hours. But the old adage, "where there's a will there's a way" will apply in this case. A private working library can be obtained very readily by a little self-denial and determination. The cost of subscriptions to the leading periodicals in any special line of work is small, and if the files are preserved they will immediately form the nucleus of a working library. Follow this rule for five or ten years, buying, as the opportunity presents itself, the latest treatises and

special works, supplemented by the published transactions of the various technical societies.

A special feature should be made of collecting general indices of engineering literature, also the special indices of certain periodicals or societies covering their own publications for a long run of years. With such a private library at hand, there will be hardly a question arising in the ordinary run of work in regard to which some valuable information cannot readily be found. For extended researches the indices will indicate what books to consult in a public library. To the expert engineer a technical working library is just as essential as a law library to the lawyer, or medical books of reference to the physician.

Admitting, therefore, the truth of the statement that much information and corroborative evidence can be found in technical publications bearing on almost every case presented for adjudication or examination to the expert engineer, the question arises as to the particular value that should be attributed to such data and evidence both from an engineering and legal point of view.

Regarded purely as an aid in settling some engineering question, it will have to be admitted by even the most casual observer that published plans and accounts of particular methods of construction and procedure in cases similar to the one under discussion are of the greatest value either in establishing precedents or correcting preconceived individual views. Recorded data of tests or the observed results of new special methods of construction play an important part in the progressive improvement of any particular line of work. In addition, general articles and statements, not written with any special work or set of conditions in mind, but aiming to cover the subject from a broad point of view, giving the pros and cons and analysing the question in all its bearings, followed by a summary, accompanied by general recommendations, will offer the intrinsic feature of representing the most unbiased opinion that it would be possible to obtain.

From a legal aspect, for use in lawsuits or proceedings before commissioners, pertinent quotations from published works of leading authorities or extracts from the technical press and proceedings of societies have the great value of standing in the light of the very best impartial evidence that could be presented, having been written and published entirely independent of, and without any possible connection with, the matter under adjudication. The presentation of such quotations and the exhibition of published plans as corroborative evidence of the statements of an expert witness are perfectly admissible after proper verification of the authenticity and the professional standing of the authority quoted. In proceedings before commissioners or committees, where the rules relating to the admissibility of evidence are relaxed, the influence of such data is often much more marked than personal testimony presenting individual views.

It is not necessary to draw on the doctrine of infallibility, because an engineer has seen fit to rush into print; but it certainly can be claimed that an author of a general treatise or a special article in a magazine or in the transactions of a society, or even the writer of a description of some engineering work, published in a technical journal of acknowledged standing, mut have studied the subject pretty thoroughly and been cognisant with the principal facts and arguments bearing on the case. His general views and conclusions may clash in some particulars with the preconceived opinions of engineers employed temporarily as experts, but the fact that the published statements were made without reference to the particular case in dispute should receive careful consideration.

It is only the man of the broadest gauge and most independent position in his profession who can be considered as absolutely unbiased in giving expert testimony. Every engineer employed as an expert witness, in fact, every witness in a case, is generally "sounded" by the lawyers prior to being placed on the stand. If the prospective witness

does not seem to be able to see the case in the desired light, he is naturally passed by. To state that all experts are biased on the stand is putting it strongly, but they are biased in the sense that they have generally expressed or indicated in a few words, prior to taking the witness chair, that they held certain views favourable to the party employing them. This is true whether the case involves medical, engineering or any other similar class of expert testimony.

Perfectly unbiased and independent testimony can probably be obtained only when experts are appointed and paid by the court or the commissioners sitting in a case, which is the method employed in several foreign countries. The views and reports of such men, aided by quotations from the published works of authorities and extracts from the technical press, will command respect and consideration.

Lawyers usually make a serious mistake by considering engineering experts in the same light as any other witness in the case. A brief conversation in regard to the particular features of the case is about all the information the average expert receives till placed upon the witness stand. Any engineer, connected with a large corporation transacting business in different cities, will readily bear testimony to the assertion that the methods of the various local counsels, all working for the same company, vary radically according to their individual temperament and peculiarities. Some discuss a case minutely with the engineer, while others actually wait till court day and then, after a whispered conversation of a few minutes, held in one corner of the court-room, enter upon the trial of the case, trusting to their legal instinct and the inspiration of the moment to pull them through.

There are lawyers whose inclinations and ideas are towards scientific and engineering questions, owing to their having, in their younger days, been members of the "chain-gang" of a surveying party or dabbled in a machine shop, or who have a hobby of following the latest developments in science and electricity. Others, through long years of experience in corporation matters, become expert in grasping and dealing with the engineering details of suits entrusted to them. But, as a rule, the engineering expert is capable of rendering much more valuable assistance as an adviser and educator in his particular sphere than acting merely as an ordinary witness.

The lawyer should acquaint his expert with all the facts in the case and then give him sufficient time to collect data, not only from his own actual practice and the practice of others, but also from the technical literature on the subject, so as to prepare an engineering brief to be thoroughly discussed with the lawyer prior to the starting of the legal proceedings. This brief and the subsequent consultation will aid the lawyer to grasp the technical details of the case and assist him in preparing a list of interrogatories and the general line for conducting the case as far as the engineering features are concerned.

In drawing on the technical literature to substantiate views to be expressed or promulgated by the expert, the entire drift of the argument employed by an author, or all the circumstances and local conditions connected with a certain class of construction, described in an article, should be considered. The reprehensible habit of extracting isolated sentences or, still worse, parts of sentences from a book, paraphrasing the quotations in the manner that advertising circulars are elaborated, cannot be too severely condemned. It can be classed as a species of sharp engineering practice, contrary to the ethics of the profession and to all sense of justice and fairness.

The extent to which this can be carried is aptly illustrated by citing a suit which turned largely on the allowable and usual width of the wing-platforms at small local railway stations. A civil engineer, who happened to be the author of a book in which a chapter is devoted to the subject of railway platforms, was summoned one morning to appear at once in the case, the fact of

his being the author of the book mentioned not even being known to the lawyer who called him.

The lawyer on the other side had a copy of the book in court and was quoting an isolated sentence from it. The author, after qualifying as expert owing to his official railroad position, promptly called attention to the unfairness of taking one sentence of fifteen words from his book without offering the context in evidence, which would have proved that the sentence in question referred to terminal or suburban stations where large crowds have to be handled, whereas ten lines above the excerpted sentence the width of narrow footwalks, extending each way along the track from the main platform at stations of minor importance, was specifically mentioned in detail and fitted exactly the case in court.

This incident emphasises the great value of quotations from engineering literature, as also the serious danger to be encountered if the quotations are not made by fair and unbiased witnesses. It also illustrates the necessity of the lawyer remaining in touch with his engineering expert throughout the case, so as to be prepared to parry every attack of his opponents.

It is frequently said that arguments, supported only by generalisation, sound well, but are not conclusive. The limits of this article do not admit of extended detail. It will enhance the value and point out the possible application of the general arguments, however, to indicate, briefly, certain engineering questions that have actually arisen in legal proceedings, in which quotations from engineering literature and the technical press proved valuable.

The specifications for a highway bridge prescribed that it should be "safe to carry a crowd." The specifications of a number of similar bridges, published in the technical journals, together with general data of engineering authors on the weight of crowds and the recommendations as to the loads to be allowed, proved of more value than the statements of several local engineers as to the weights they "thought" were sufficient. In a suit relative to the import duties to be paid on creosote or dead oil of coal tar, the case turned not only on excerpts from chemical books, but mainly on the attempt to establish the proper classification of the material based upon its popular nomenclature and the particular trades and industries it was used in, as evidenced by numerous quotations from engineering and industrial books and periodicals.

In a suit by a contractor to get an extra allowance for rock excavation outside of the actual theoretical grade lines of a public street, in the absence of any specific clause in the contract referring to the question, the practice of leading engineers of the vicinity had to be drawn on, supplemented by published specifications for similar work at other points and also by extracts from a general treatise on highway construction.

In the establishment of a refrigerating plant the efficiency of the insulation of the walls, as furnished by the contractor, being questioned, some published descriptions and plans of similar installations, and especially a general article by an eminent professor on the subject of the value of various insulating methods, were utilised.

A heavy piece of machinery subject to severe vibrations was specified to have a "suitable" bed. The question turned on what were the essential features for a bed under these circumstances. A descriptive article in an engineering magazine on foundations of steam hammers and heavy machinery established some of the principal requirements.

A railroad company brought forward as an element for damages that it was being forced to build a yard with a grade across the yard, whereas a yard should be absolutely level crosswise. No attempt was made to draw on technical publications, but, if there had been, data could have been brought forward showing the practice and the desirability of building with a slight grade crosswise to allow for side drainage of the roadbed.

Many similar cases might be cited, but these few should suffice, in connec-

tion with the general arguments given above, to show the importance of the technical press and literature, not only as an aid to the engineer in designing and executing work, but also as a valuable adjunct to engineering expert testimony.

FRANCIS WILLIAM WEBB, M. INST. C. E.

LOCOMOTIVE SUPERINTENDENT OF THE LONDON AND NORTH WESTERN RAILWAY.

By J. N. Jackson.

CREWE, the great English railway town, the pivotal point, so to speak, of the London and North Western Railway,—what engineer has not heard of it? Railway men everywhere have looked to it for years as a source of inspiration, a well spring of profitable experience, and a visit to its shops, with their army of workers, toiling unceasingly for the maintenance of a great railway system, has always been full of promise of things worth knowing, of methods and machinery typical of the most advanced practice in railway engineering.

The shops date back to 1843, when, under the superintendence of Mr. Trevithick, 150 men formed the beginning of a working population that, since then, has grown to nearly 20,000. To these shops Mr. Webb came in 1851 as a pupil, serving there until 1866, by which time he had risen to the position of works manager. The five years following were passed by him as manager of the Bolton Iron and Steel Company, but in 1871, he returned to Crewe to succeed Mr. Ramsbottom as locomotive superintendent, and this position he has retained to the present time.

During this period of 25 years the North Western system developed rapidly, and with it, as may be inferred readily enough, Mr. Webb's particular department of locomotives, which, it should be said, is not confined simply to the supply and repairs of locomotives, but which includes, also, the manufacture and repairs of the general machinery required up and down the line, such as cranes, hydraulic and electrical machinery, signal apparatus, girders for bridges, and the numberless mechanical appliances used in railway working, and it is due to Mr. Webb's skillful supervision that this vast amount of work is carried through with such satisfactory results.

As showing the despatch with which he can get work turned out when urgently required, it may be mentioned that when, during the great storm, in 1879, the viaduct at Llandulas, on the main line of the Chester and Holyhead Railway, was completely washed away by the heavy flood, it was imperative that it should be reconstructed with the least possible delay, although a temporary trestle bridge was thrown over the river to enable the traffic to be continued. For this purpose forty-two steel girders were required, each thirty-two feet long. The order for these was placed in Mr. Webb's hands, and he immediately set to work to make them at Crewe, and within seven days the steel for these was made, the plates and angles were rolled, and the whole of the girders turned out ready for fixing in their places.

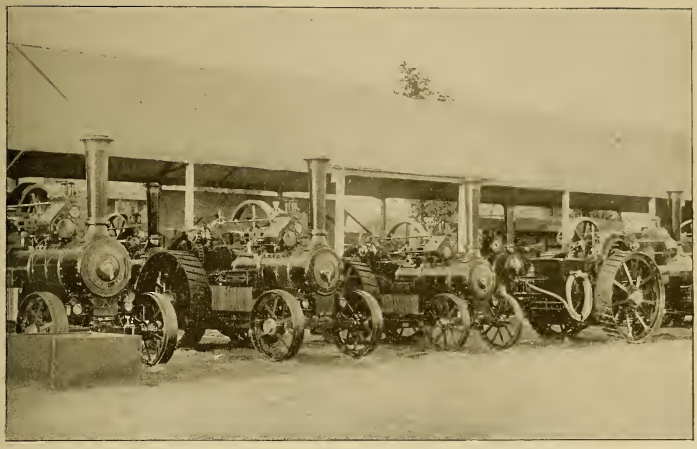
Mr. Webb is the patentee of the signal interlocking apparatus now in use throughout the London and North Western Railway, and also of many other

well known mechanical and electrical appliances connected with railways. But it is as the inventor of the 3-cylinder compound locomotive that he is perhaps best known throughout the railway world at home and abroad.

On the introduction of these engines in 1882 they met with a considerable amount of adverse criticism, but Mr. Webb subjected them to such severe tests in order to prove their efficiency, and the results of the last 13 years' continuous working with the heavy and fast express trains over the main line of the London and North Western Railway have proved that they possess all the advantages claimed for them, that they are now generally admitted to be a success. Of course, since their first introduction, Mr. Webb has made many improvements in the details of these engines, the principle, however, remaining unaltered, and one of the last class built—the "Queen Empress"—was exhibited at the World's Fair, at Chicago, in 1893, at the close of which she started on her homeward journey, running in steam from Chicago to New York with a train of two English and three American saloon cars.

Mr. Webb is a member of the Council of the Institution of Civil Engineers, a member of the Council of the Iron and Steel Institute and also a life member of the Institution of Civil Engineers of France. He is a life fellow of the Imperial Institute, and is also connected with many other minor institutions whose members frequently benefit by his extensive knowledge and experience of railway and general engineering subjects. He is, too, a magistrate of the county of Cheshire, and an alderman of the Cheshire County Council.

As president of the Crewe Mechanics' Institution he has done much to advance the intellectual welfare of the students attending the technical and science classes held there, and who are, for the most part, apprentices and young men employed in the railway works at that place. He has twice filled the office of Mayor of Crewe,—in 1887, the year of the Queen's jubilee,—and in 1888 when the London and North Western Railway jubilee was celebrated.



MODERN ENGLISH TRACTION ENGINES.

By William Fletcher.

AT the present moment the question of rapid transport over common roads is occupying the attention of many minds. It is a fascinating subject, and one that has been dealt with very fully of late. England is sadly handicapped in the race, owing to an oppressive law that will not allow motor carriages to travel more than four miles an hour in the open country, and two miles an hour when passing through towns. Since this law was passed, some good steam carriages have appeared in Great Britain, but they have moved about only at slow rates on the public roads, and shown their powers at fast speeds on private grounds alone.

Practically the light steam carriage enterprise was strangled in its cradle. In the meantime, however, a considerable amount of thought has been brought to bear upon the heavy slow-moving traction engine. The modern traction engine cannot be dispensed with, in spite of the irritating opposition that is raised against it by a class of persons who object to the employment of any power, except animal power, on the highway.

For many years the traction engine industry in England remained principally in the hands of three or four leading makers, but at the present time there are about twenty firms engaged in the enterprise, all of which are in a position to supply the engines. There are more minds devoted to the improvement of the traction engine than ever, and there are more men interested in its development, so that it is no matter for surprise that the efficiency of the engine has recently advanced in leaps and bounds.

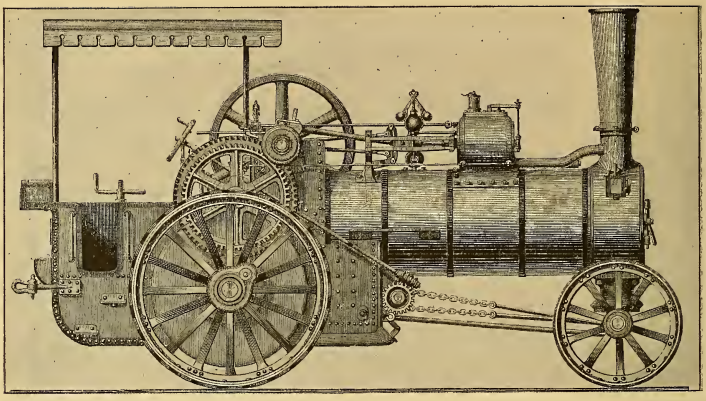


FIG. 1. AN AGRICULTURAL LOCOMOTIVE. BUILT BY A NEW HAND.

It is not many years since the English traction engine showed very little evidence of drawing office care in its design. The details looked as though they had been thrown into position, giving the engine a very hap-hazard appearance. There was little attempt to cover the gearing or working parts, and the movement of these grotesque and miscellaneous wheels, rods, and exposed crankshaft, caused the engine, when in motion on the road, to look like a factory out for an airing. We do not wonder that horses and some men were terrified when they met these wheezing, groaning, and smoking abominations on the highway.

But all this has been changed; the engines have undergone a series of revisions; every part has passed through the mill of the mind. Pleasing and graceful appearance is now considered to possess much value, and many have aimed at this with happy results.

To design a really efficient and neat looking traction engine requires a considerable amount of experience, and an ability of a special kind. Even many years of experience alone do not furnish the requisite qualification. The designer of a good traction engine must be able to see, at a glance, whether a detail is of the necessary form and strength for its intended purpose. Mathematical knowledge does not render much help. In the case of some designers of good traction engines, this kind of knowledge was limited; but this deficiency has never disqualified a practical man from producing an engine that was soon a general favourite among buyers. Calculations as to proportions appear to be quite useless; the sizes and strength of gearing, brackets and shafts have been, and can be, decided only by years of actual work, failure after failure leading eventually to success.

We know of one engine over the drawings of which figures ran wild; calculations were made by the square yard, but the machine, when built and put to the test, proved a disastrous failure. Another agricultural locomotive comes to mind which was designed several years ago by an engineer with no experience in traction engine manufacture. While the drawings were in preparation no suggestions were forthcoming from the foremen, or officials, as all the staff was new to the branch. The first engine was quickly built, and, without any delay, was taken from the shops and put through some severe trials on the road. It was taken ten miles away from the works the first day, and made to mount a very steep hill in fast gear. During

these trials no alterations or failure of any kind took place, neither were any modifications made in the engine after the test, but it was speedily dispatched to the purchaser, who had work of various kinds waiting to which the engine was at once applied. This number one traction engine gave every satisfaction, and was christened "Success." Many more engines were afterwards made to the same plans, and the makers occupy a prominent position among the firms who produce good traction engines. The engine is shown in Fig. 1, not because it is a modern type, but because some interest is attached to it.

The following types of traction engines are made in England at the present time :—1. Agricultural locomotives for threshing purposes. 2. General purpose traction engines, used for threshing and for hauling occasionally. 3. Road locomotives for continuous hauling work on roads. 4. Light traction engines for running at quick speeds for parcel and passenger service in foreign countries. 5. Self-propelling ploughing engines.

Any of these engines can be made suitable for burning wood, straw, reeds, cotton-stalks, or oil as fuel. They may be mounted on springs or fitted with spring wheels. They are made on the simple, or on the side-by-side compound plan.

There are two systems of construction which must be referred to here, in order to save much repetition in the description of the engines. They are termed four-shaft, or inside gear traction engines; and three-shaft, or outside gear engines. In a four-shaft engine, there is a crankshaft, two countershafts, and a main axle; in a three-shaft engine there is a crankshaft, one countershaft, and a main axle.

Messrs. Aveling & Porter, of Rochester, England, have for many years taken a leading position in the manufacture of traction engines. Fig. 2 shows one of

FIG. 2. COMPOUND ROAD LOCOMOTIVE. BUILT BY MESSRS. AVELING & PORTER, ROCHESTER.

their compound road locomotives, specially intended for continuous hauling work on the roads. The high and low-pressure cylinders are placed side by side at the smokebox end of the boiler, the pistons and connecting rods actuating a double-throw crankshaft.

In order to place the slide valves close to the top of the cylinder, the valve rods are arranged on an incline. Some of the gearing is placed inside the box brackets between the bearings. The side plates of the boiler are carried upward, and at the top a strong casting is secured. In this casting are combined the bearings for the crankshaft and the two countershafts, forming a substantial arrangement for keeping the spur gearing in proper working condition.

A worm barrel is provided for the steering chains to coil on, preventing the chains from mounting, and for taking up the slack. The feed pump is fixed on the boiler barrel, the suction pipe leading direct into the pipe which connects the two tanks as shown. The engine parts are boxed in, and the gearing is covered. The equipment is complete, and care has been expended on the design and construction of this engine so as to render it in every way worthy of the name it bears. Such engines leave little to be desired on the scores of simplicity, strength, durability and economy in working.

The compound engine shown in Fig. 3 is built by Charles Burrell & Sons, of Thetford. A dynamo is mounted on the smokebox end of the boiler, for illumination at night. The engine is mounted on springs which secure a great saving in wear and tear of the working parts. An awning covers the tender and some of the working parts of the engine, and a rail is fixed round the coal bunker in order to increase the fuel capacity. The water lifter and hose are attached to the fore tank as shown. It is very evident that a good appearance has been aimed at with the best results. This firm has probably built a larger number of types of road engines than any other maker, and not one of these types has fallen short of success.

Fig. 4 shows a twin compound agricultural locomotive made by Messrs. Foden Sons & Co., of Sandbach. The cylinders are steam jacketed and well lagged. The front cylinder covers have each a cylindrical guide cast with them as shown. The guides are bored and turned at one setting, which makes them absolutely central with the bore of the cylinders. On the top of the guides is fixed a Porter governor which actuates a throttle valve in a direct manner. The sides of the box brackets are made of boiler plates, riveted to the arch plate, and stiffened by transverse plates.

All Messrs. Foden's engines are mounted on springs. The axle and the countershaft are securely held together by links on each side, and the bearings for both these shafts slide in a strong bracket. On the top of each bracket there is a circular box containing a large square steel spiral spring. The weight of the hind part of the engine and the boiler, passes through the springs to the main axle. There is also a similar spring on the fore axle, kept in place by a cylindrical turn plate.

The tires of the driving and leading wheels are made of tough cast-iron, the former being shod with steel diagonal strips. The driving wheels are nearly seven feet in diameter; the advantages of large drivers are too well known to need any remark here. It will be noticed that a larger number of spokes are adopted than usual, the iron being of a smaller section. The water in the supplementary tank under the boiler barrel, is heated by a portion of the exhaust steam. The pump draws its supply from this tank.

Another road locomotive, specially built for hauling showmen's paraphernalia from town to town is shown in Fig. 5, and is manufactured by Messrs. John Fowler & Co., of Leeds. The engine illustrated, enables circus proprietors to be independent of the railway companies, the cost of road haulage being from 50 to 80 per cent. less than by rail. The owner of this engine says:—"I may tell you that in passing through Jarrow-on-Tyne, the engine and its train of ten wagons had to travel in awkward streets, parts of the train

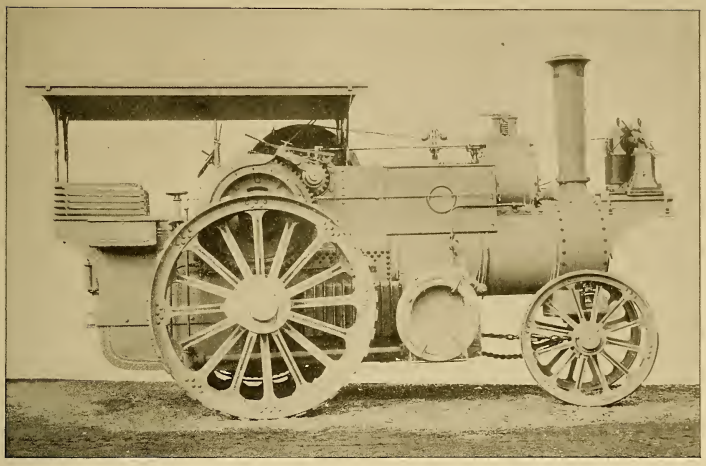


FIG. 3. COMPOUND ROAD LOCOMOTIVE. BUILT BY MESSRS CHARLES BURRELL & SONS, LTD., THETFORD.

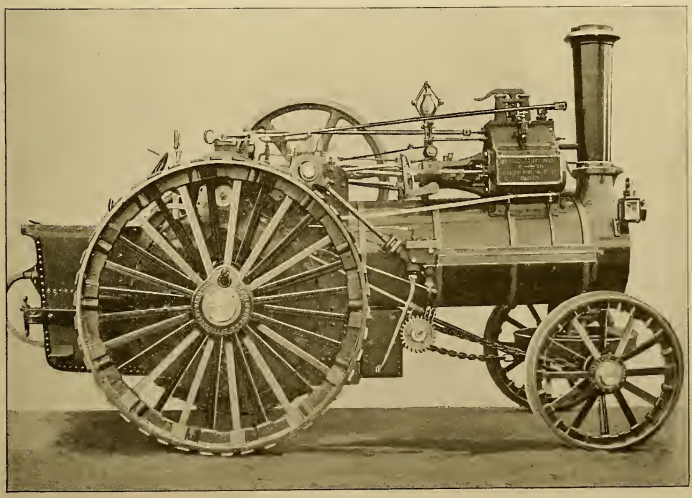


FIG. 4. COMPOUND AGRICULTURAL LOCOMOTIVE. BUILT BY MESSRS. E. FODEN, SONS & CO., LTD., SANDBACH.

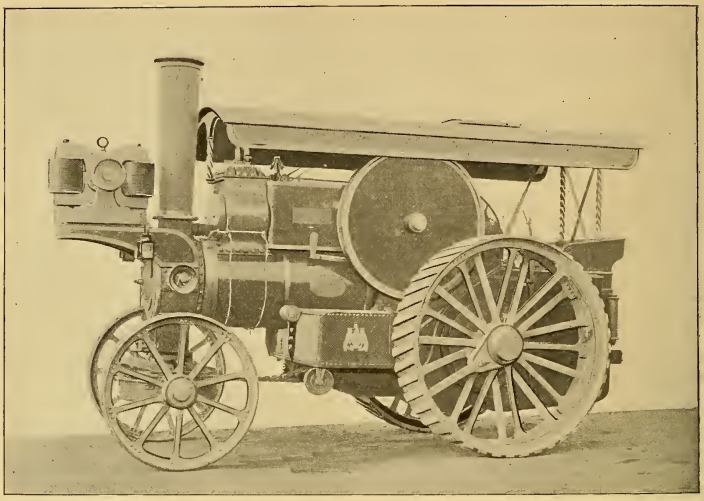


FIG. 5. COMPOUND ROAD LOCOMOTIVE. BUILT BY MESSRS. JOHN FOWLER & CO., LEEDS.

being in three streets at one time, forming something like an S. In the winter time I frequently travel thirty miles a day with a load of nearly fifty tons."

The engine is of the double-crank compound type, and is well mounted on springs. The vertical play due to the action of the springs has been registered automatically when passing over rough roads. When running at two miles an hour the vertical movement is half an inch; when running at four miles an hour it is about an inch; and when going at the rate of six miles an hour, the vertical play is one and a quarter inches. A dynamo is fixed on a platform at the front, driven by a belt from the fly wheel of the engine. Messrs. Fowler have supplied a considerable number of these engines, for drawing from thirty to fifty tons.

Fig. 6 represents one of Messrs. Fowler's single-cylinder, general purpose traction engines. The illustration is self-explanatory. All the best features of a modern traction engine intended for threshing and general work are embodied in this example. The high speed governor and equilibrium throttle valve render the engine particularly suitable for steady driving.

A newly designed traction engine made by Messrs. Richard Garrett & Sons, of Leiston, is shown in Fig. 7. It is intended for threshing and general work. The single cylinder is bolted to the boiler barrel in the usual manner, having a wide flange all around for taking a good bearing on the boiler. The ordinary slide bars are dispensed with, and a bored guide takes their place. The usual link motion has been discarded to give place to a single eccentric reversing gear of simple construction, patented by Messrs. Mann & Charlesworth, of Leeds.

Messrs. Garrett's engine is of the four-shaft type. The governors are of the Pickering type. The engine is a substantial piece of work and possesses all the up-to-date accessories of the modern traction engine, such as a winding drum and wire rope, a brake, and a water lifter and hose pipe for filling the tank from a brook on the road side. The drawbar on the tender has

straps on the sides for taking the strain, thus preventing the pull of the engine from making the tank leak.

Fig. 8 represents a very neatly designed agricultural locomotive, made by Messrs. R. Hornsby & Sons, of Grantham. There are several features of interest that distinguish this engine from those already described. It is an outside gear engine. The box bracket plates are riveted to the firebox shell, having transverse plates riveted in between them to give them the requisite stiffness. A neat bracket carries the two slide bars, the governor and throttle valve spindle, the valve rod guide, and the bar for the reversing gearing. The whole of the steel driving gear is cased in to preserve it from the dust, and to suppress noise.

The dome on the top of the cylinder is in direct communication with the steam jacket round the barrel of the cylinder, and these spaces combined form a large reservoir, from the highest part of which the steam enters the stop valve. The governor is of the cross-armed or approximate parabolic type, very sensitive in work. A wooden platform is provided on the side of the boiler barrel, from which the engine driver can reach to oil or clean all parts of the engine. Underneath this foot board a very large toolbox is hung. A round tray is fitted on the front axle for carrying loose tools, chains, etc. All the handles and levers are conveniently arranged, so that one man can, if required, drive and steer the engine.

The agricultural locomotive shown in Fig. 9 and built by Messrs. Mann & Charlesworth, of Leeds, possesses several novel features. The ordinary link motion reversing gear has been dispensed with, and in its place the firm's patent single eccentric reversing gear has been applied. This enables one eccentric and rod to do all that is required in working expansively when running forward or backward, and for reversing the motion. The eccentric is shifted from full forward to full backward without altering the lead. Its movement resembles that of the par-

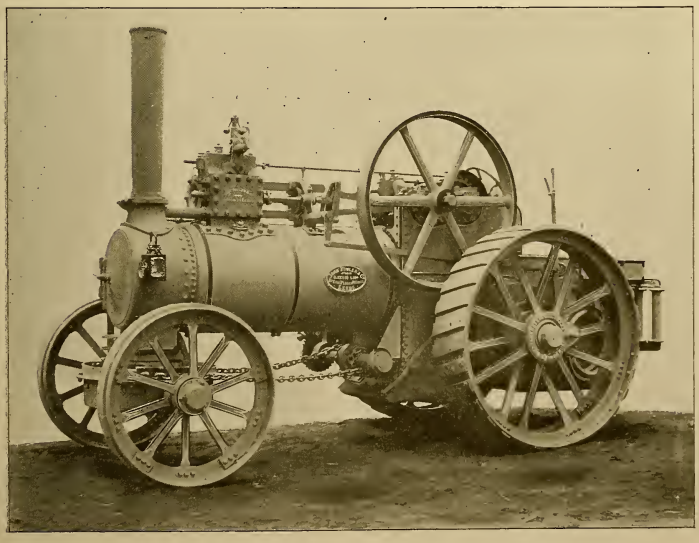


FIG. 6. SINGLE-CYLINDER ENGINE. BUILT BY MESSRS. JOHN FOWLER & CO., LEEDS.

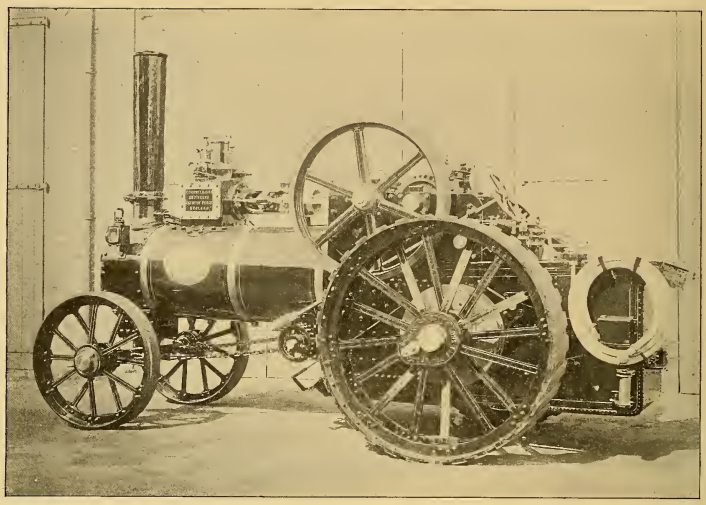


FIG. 7. AGRICULTURAL LOCOMOTIVE. BUILT BY MESSRS. RICHARD GARRETT & SONS, LEISTON.

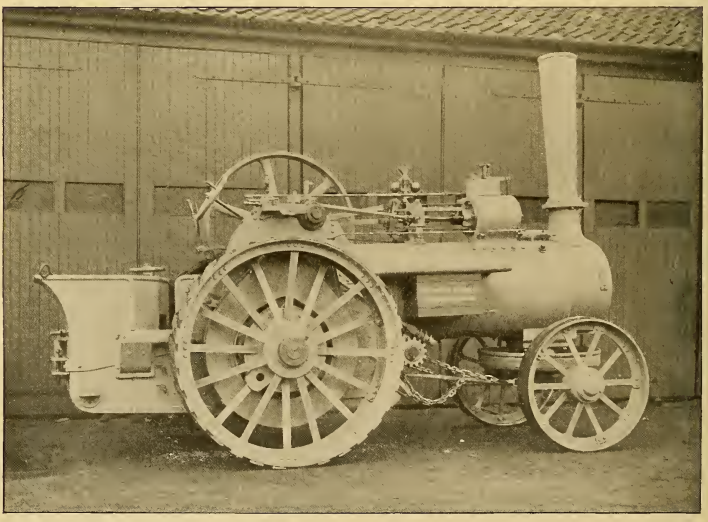


FIG. 8. AGRICULTURAL ENGINE OF MESSRS. R. HORNSBY & SONS, LTD., GRANTHAM.

allel ruler, as in any position it remains parallel to the centre line of the engine and at right angles to the crankshaft. There are three bearings for the crankshaft, and the driving pinions for the two speeds are placed between two of these bearings, but outside the box bracket. The governor is fixed over an equilibrium throttle valve in the cylinder. By using steel castings in place of cast-iron the weight has been considerably diminished without reducing the strength, or limiting the efficiency.

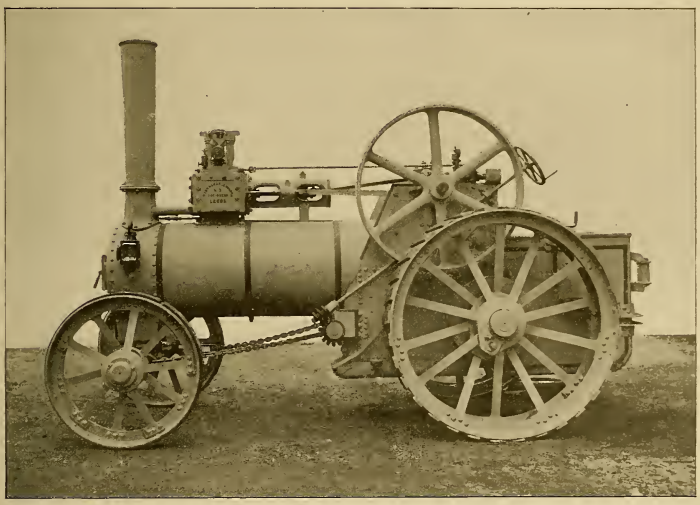


FIG. 9. LOCOMOTIVE BUILT BY MESSRS. MANN & CHARLESWORTH, LEEDS.

In Figs. 10 and 11 are shown both sides of a very well designed agricultural locomotive, made by the well known firm Messrs. Marshall, Sons & Co., of Gainsborough. These traction engines have been improved from time to time and possess all the latest devices suggested by a long experience. It is impossible to speak too highly of the efficiency and good workmanship of Messrs. Marshall's productions. The cylinder is thoroughly steam-jacketed, and the steam supply, the circulation and the drainage of the jacket have received careful attention. Bored guides are used instead of the usual slide bars, and the outer end is supported by a bracket that serves as a guide for the valve rod, and a stand for the governor and throttle valve spindle, as well as for the details of the reversing gear.

The sides of the tender are flanged so as to reduce the riveting, increase the strength and give the tender a neater appearance. Some of the gearing is placed in the box bracket; the remaining gearing outside the plate is effectively covered in to protect it from dust and dirt. The steerage worm wheel is placed inside the bearing, instead of outside, as is the usual practise. The engine is fitted with strong compensating gear, a slip winding drum and all the usual tools and appliances for rendering the engine complete and ready for any emergency to be met with in regular threshing or occasional hauling work.

Another prominent firm engaged in the manufacture of traction engines, is

Messrs. J. & H. McLaren, of Leeds. In Fig. 12 is shown one of their newly designed agricultural locomotives. This engine is of the four-shaft type. The weight of the engine has been considerably reduced, in fact there is a desire among the best makers to take away all superfluous material in the details and to replace heavy cast-iron brackets with much lighter ones made of steel. By these alterations the strength, and the efficiency of the engines are considerably increased. Messrs. McLaren, too, have adopted the bored guide. The engine is a thoroughly sound and trustworthy piece of workmanship, the design embodying the improvements suggested by seventeen years' experience.

Fig. 13 shows a single cylinder, general purpose traction engine made by Messrs. Ransomes, Sims & Jefferies, of Ipswich. This engine is suitably equipped for use in the colonies. The greatest care has been bestowed on it, so as to render it as simple as possible. The number of details has been cut down to the utmost limit, but in no case has real efficiency been sacrificed thereby. All the latest improvements have been embodied in the design, while the workmanship is of the highest description—equal to the work produced in the best railway locomotive shops. The boiler is made entirely of steel and suitably stayed for a working pressure of 140 pounds per square inch. Before being erected the boiler is subjected to a water test pressure of 240 pounds per square inch. The plates are flanged by hydraulic pressure, and the riveting is also done by the same means.

The steel shafts and main driving axle are carried in brackets, fitted into the side plates of the firebox shell, which are extended upward and backward for the purpose. These side plates are stiffened by flanged transverse plates which are riveted in as shown. This forms a box in which the crank, the eccentrics and the first motion gearing are nicely arranged. The engine is fitted with compensating gear on the main

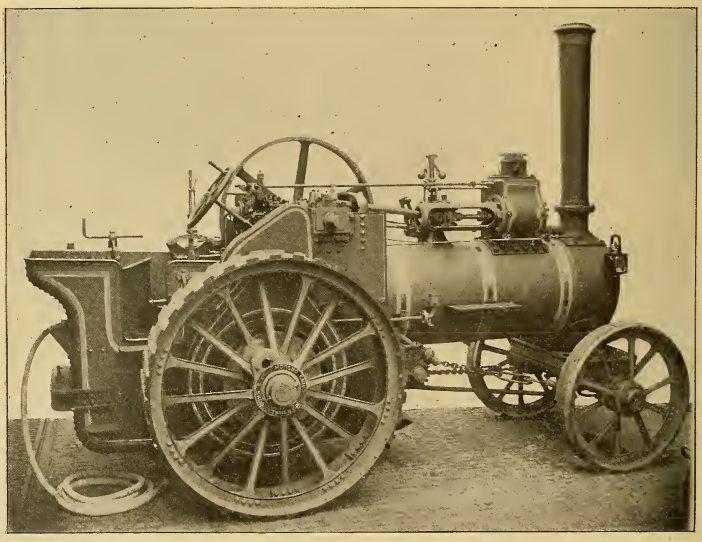


FIG. 10 AGRICULTURAL LOCOMOTIVE. BUILT BY MESSRS. MARSHALL, SONS & CO., GAINSBOROUGH.

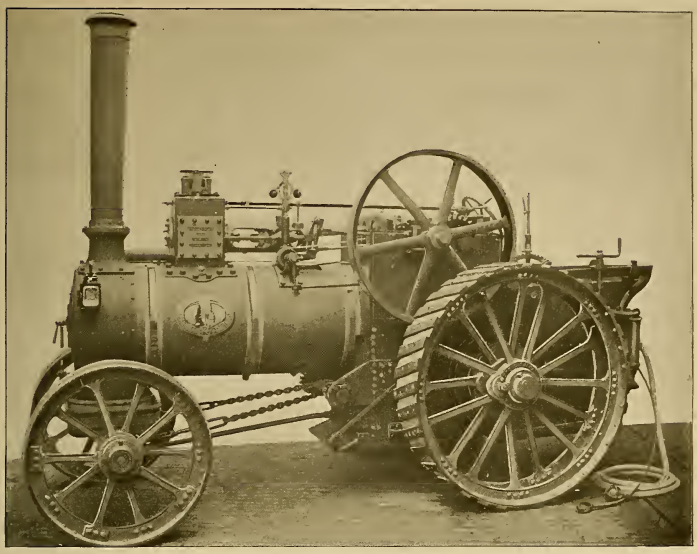


FIG. 11. THE OTHER SIDE OF THE ENGINE SHOWN IN FIG. 10.

axle, so that it can turn sharp curves without loss of tractive power. This gear relieves the axles of much strain, and, when necessary, the differential gearing can be locked, so that both wheels revolve with the axle. On the main axle the winding drum is also fixed. This drum is so made that the steel rope can be paid out as the engine travels forward,—an arrangement that effects a great saving of time.

Suppose we wish to haul a heavy load up a steep hill with the drum and wire rope. Instead of taking the engine up the hill and pulling the rope out by hand, as was formerly done, it is only necessary to attach the rope to the wagon to be hauled up and run the engine to the summit of the hill, paying out the rope all the time. By pressing down a spring pin the drum is then put into gear, and the rope is wound up without a moment's loss of time. The whole of the spur gearing is made of cast-steel, so that breakages are rarely heard of, and the wear is reduced to a minimum. Two speeds are provided,—one for drawing heavy loads up hill, or over bad roads, at two miles an hour; and the other, for lighter loads on level and good roads, giving a speed of four miles an hour. The arrangement of this gearing is such that only one lever is required for changing the speed, and one pinion is thrown out before the other is put in gear.

All the shafts, axles, piston and valve rods are of steel. The pins, joints and general wearing parts are made of ample dimensions for reducing the wear to the utmost, while special care is devoted to the proper case-hardening of these parts. The cylinder is steam-jacketed, so that neither air nor water can be trapped and retained in the jacket. When running on the road, the governor is not used, but when the engine is used, as it can be, for driving machinery by a belt from the fly wheel, the governor is required.

A second tank is fitted under the boiler barrel, carrying an extra quantity

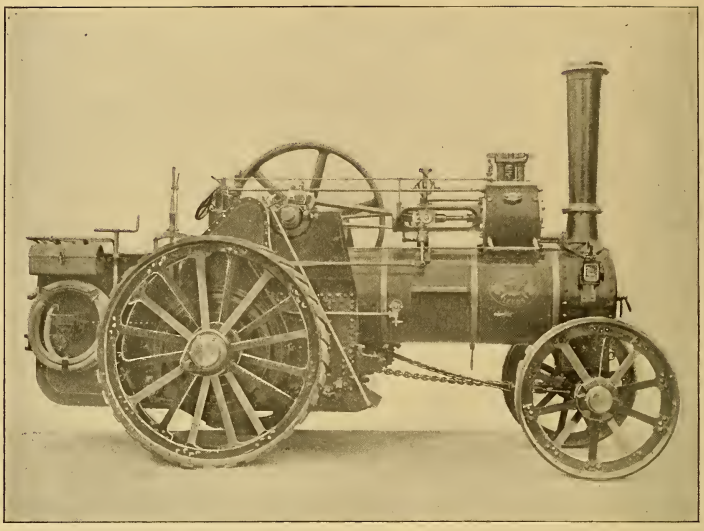


FIG. 12. AGRICULTURAL ENGINE OF MESSRS. J. & H. MCLAREN, LEEDS.

of water, and both tanks are connected by means of a pipe. A good bit of road can thus be covered by less frequent stoppages for water. A cab is provided for sheltering the driver from the sun or the rain; it also covers the box bracket and the working parts in it. A foot plate and ladder are fitted for the use of the driver when oiling or cleaning the engine. On the front axle there is an iron box for carrying the anchors, the hauling chains, frost spikes, cotters, etc. The engine is complete in all particulars, thoroughly economical in fuel, efficient in work, handy to manage on the road and has no details likely to get out of order or give trouble. The whole work is very sound and good, and fairly represents an example of one of England's best make of traction engines.

Fig. 15 shows one of Messrs. Ransomes, Sims & Jefferies' improved agricultural locomotives of the single-cylinder type. A large number of these engines have been manufactured and are doing excellent service on farms.

A few years ago there was every indication that the compound traction engine would become very popular, but this result has hardly been realised. The compound engine has been adopted in many cases, but those makers who have specially boomed their compound engines still continue to make a good number of single-cylinder engines. Some firms say, "We can supply traction engines made on the compound principle, but we recommend the single-cylinder engines, as, with the latest improvements, they work very economically and have only half the number of parts." There are other manufacturers who are prepared to supply compound engines, but who are rarely asked for them. The greater proportion of their orders are for single-cylinder engines.

For continuous hauling work, however, the compound engine must be recommended. If this type of engine is worked at the full boiler pressure of 150 lbs. per square inch, a saving of thirty per cent. in fuel and water will be secured. The noise produced by the exhaust steam also is reduced, which is

an advantage. The shocks upon the crankpins, gearing and other working parts are less severe. An auxiliary valve is provided which allows high pressure steam to enter both steam chests, and both the cylinders exhaust into the common exit pipe (the compound principle being suspended for the moment), enabling the engine to start readily with a heavy load behind. As soon as the engine is under way the valve is closed. A relief valve is fixed on the low-pressure steam chest.

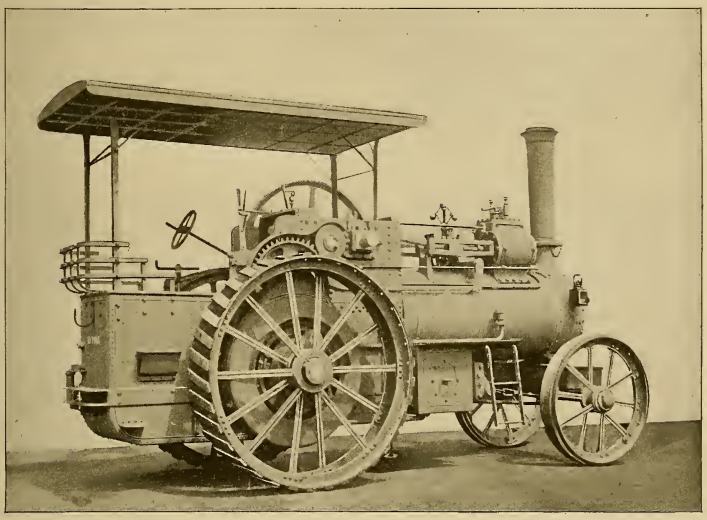


FIG. 13. COLONIAL TRACTION ENGINE OF MESSRS. RANSOMES, SIMS & JEFFERIES, IPSWICH.

For threshing purposes the compound engine cannot be so fully recommended on account of the reduced steam pressure employed for threshing,—from 80 to 100 lbs. pressure being quite sufficient. Not only so, but for this work the attendants are often very unskillful, so that it is an advantage to have the simplest possible engine. The first cost is also a consideration with the threshing fraternity. While on the subject of cylinders we may refer to the proposal to bolt the cylinder on a wrought steel fixing or girder, instead of bolting the casting direct to the boiler barrel as heretofore. The base of the cylinder and the seating are planed, so that, having a flat surface, the joint is more easily made and retained. None of the bolts pass into the steam space. For export engines this method of construction possesses important advantages. Beyond this there does not seem to be any great value in the plan.

Now that steam pressures are steadily creeping up, some makers have experienced trouble in keeping the joint tight under the cylinder, around the steam inlet, but if the joint is properly fitted there will be no fear of leakage. In Fig. 16 is given a section of a traction engine cylinder in order to show the steam opening from the boiler, and one method of making a steam tight joint. It will be seen that the cylinder is tapped to receive a pipe which passes through the boiler plate ; on the under side of the plate a properly shaped washer is fitted, and a nut is screwed tightly up

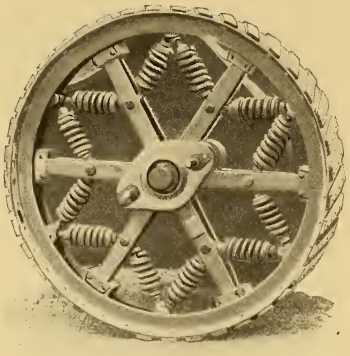


FIG. 14. A SPRING WHEEL.

to it. On the bottom end of the pipe a steam collector is also screwed.

In Messrs. Ransomes' traction engines this steam joint trouble is nicely remedied. The cylinders in their engines have no steam inlet hole under the foot, but the steam is conducted into the cylinder by a separate elbow, so arranged that the joint is easily made and rarely leaks after it is once fixed in position. The bolts around the cylinder foot have to make their own joint only, and if the bolts are turned taper under the head and fit the holes in the boiler plate, iron to iron, without red lead, they will never leak.

The cylinders are always steam jacketed. The outside shell is generally made of good iron, and the liner is made of specially hard iron and is forced into its place by hydraulic pressure, the annular space between the liner and the shell forming a roomy jacket, as shown in Fig. 17. This jacket space communicates direct with a chamber on the top of the cylinder, which answers the same purpose as a dome. By the arrangement shown, circulation of the jacket steam is secured.

The steam chests of compound engines are often placed on the outside, so as to be easy of access for examination. When placed between the cylinders, they are troublesome to get at, unless they are arranged some distance

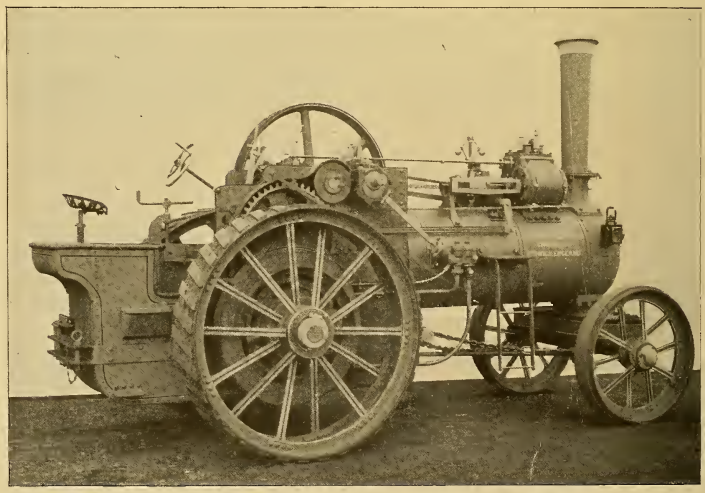


FIG. 15. AGRICULTURAL LOCOMOTIVE. BUILT BY MESSRS. RANSOMES, SIMS & JEFFERIES, LTD., IPSWICH.

above the centre line of the cylinders, in fact, as near to the top of the cylinder as possible, the valve rods and valve faces being inclined so as to point to the centre of the crankshaft. The enormous friction of a large slide valve for a single-cylinder traction engine has

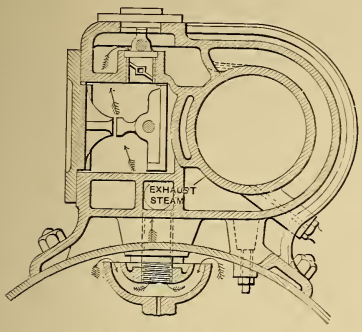


FIG. 16. SECTION OF A TRACTION ENGINE CYLINDER.

been obviated by the application of the compound engine; the high pressure slide valve is of small dimensions, and, working on the compound principle, it is partially balanced.

For want of space we have been compelled to omit some remarks with illustrations of rigid wheels, compensating gear, winding drums and driving gearing. We illustrate, however, at least one form of spring wheel. Inventors from the earliest times have been busy devising spring wheels for traction engines. Some of these answered well, and many were made, of a few different types, but most of them soon showed some constructional defect,—generally in the quality of the steel of which the springs were made. The constant jar on the road caused the material to become so brittle that the spring spokes, or the volute springs between the arms and the tires of the wheels, sooner or later gave way, and there are very few spring wheels at work at the present time.

One of the latest examples of a spring wheel is shown in Fig. 14. The engraving represents Mr. Link's wheel, in which the weight carried is equally distributed through the various details of the wheel. One extremity of the twelve spiral springs is attached to the double spokes, and the other end is secured to the tee-iron rings. By withdrawing the pins, any of the springs can be removed or replaced without interfering with any other part of the wheel. On the spokes, near the sole of the wheel, are cast-iron blocks, which do not touch the inside of the tire, but sufficient space is allowed for their movement, and in order to prevent any play sideways, steel plates are fitted on to the blocks which fit in and fill up the space between the webs of the tee-iron rings.

When a new agricultural locomotive is sent to a customer, it is usually put to a few days' heavy threshing work on several kinds of grain. If the samples are satisfactory, the engine is next made to haul the threshing machine through a ploughed field. If the land be wet,

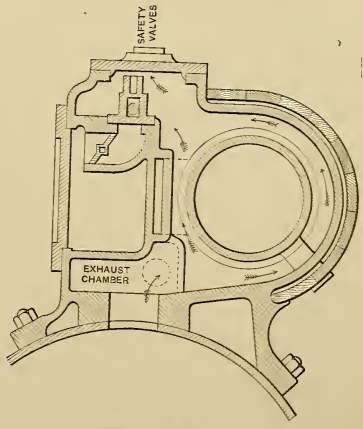


FIG. 17 SECTION SHOWING IMPROVED CONSTRUCTION.

so much the better as a test of the hauling power. The engine is next coupled to a heavy load on the road, and, if possible, on a steep gradient. In days gone by we have seen engines deeply engulfed in a ploughed field and

Table of Dimensions of Simple and Compound Road Locomotives.

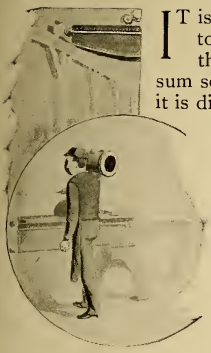
Nominal horse-power	6	8	10
Indicated horse-power	30	40	50
Diameter of cylinder, single	8 in.	9 in.	10 in.
Stroke of cylinder, single	12 in.	12 in.	12 in.
Diameter of high-pressure cylinder, compound	5¾ in.	6½ in.	7 in.
Diameter of low-pressure cylinder, compound	9 in.	10 in.	11 in.
Stroke of both cylinders, compound	12 in.	12 in.	12 in.
Working steam pressure, single	125 lb.	125 lb.	125 lb.
Working steam pressure, compound	145 lb.	145 lb.	145 lb.
Revolutions of engine governing, per minute	180	180	18
Revolutions of engine on the road, per minute	240	240	240
Total heating surface, single	120 sq. ft.	160 sq. ft.	200 sq. ft.
Grate area, single	4½ sq. ft.	6 sq. ft.	7½ sq. ft.
Total heating surface, compound	108 sq. ft.	144 sq. ft.	180 sq. ft.
Grate area, compound	4¼ sq. ft.	5½ sq. ft.	7 sq. ft.
Diameter of driving wheels	6 ft.	6½ ft.	7 ft.
Width of driving wheels	14 in.	16 in.	18 in.
Slow gear ratio	25 to 1	27 to 1	30 to 1
Fast gear ratio	17 to 1	18 to 1	20 to 1
Diameter of leading wheels	4 ft.	4½ ft.	4¾ ft.
Width of leading wheels	8 in.	9 in.	10 in.
Diameter of main axle	4½ in.	5 in.	5½ in.
Diameter of crankshaft	3¼ in.	3½ in.	3¾ in.
Diameter of crankpin	3½ in.	3¾ in.	4 in.
Pitch of first motion spur gearing	1¾ in.	2 in.	2¼ in.
Pitch of second motion spur gearing	2 in.	2¼ in.	2½ in.
Pitch of third motion spur gearing	2¼ in.	2½ in.	2¾ in.
Diameter of compensating gear bevel wheels	2¼ ft.	2½ ft.	2¾ ft.
Pitch of compensating gear bevel wheels	2¼ in.	2½ in.	2¾ in.
Slow traveling speed in miles per hour	2	2	2
Fast traveling speed in miles per hour	4 to 5	4 to 5	4 to 5
Diameter of fly wheel	4 ft.	4½ ft.	5 ft.
Width of fly wheel	6 in.	6 in.	6¼ in.
Weight of engine in working trim	10 tons.	12 tons.	15 tons.
Approximate load hauled on fairly level roads	18 tons.	25 tons.	32 tons.
Total width of engine	6 ft.	6¼ ft.	6¾ ft.
Total length of engine	16 ft.	18 ft.	18½ ft.

unable to extricate themselves; but the modern traction engines of the best makers are rarely if ever found wanting in any of the trials. They will traverse nearly any kind of land with a threshing machine and stacker behind, and on good roads they will haul nearly as much load as is given in the above table of dimensions. This table is extracted from the writer's book, "Steam Locomotion on Common Roads," in the hope that the dimensions will enhance the value of the paper.

It may be thought that the engines illustrated present a somewhat similar appearance. This is true respecting the general arrangement of the parts, but as regards the details it is very wide of the mark. There are some features of the modern traction engine which have certainly settled into a beaten track, but we see no reason for regret if the path leads to highest results. Slight alterations and improvements are constantly taking place. Keen competition among the manufacturers compels them to make frequent modifications of the design, so as to keep abreast of the times. Finality will probably never be reached, but the traction engines described here possess all the well tried devices, show the best in design and construction and are undoubtedly the "survival of the fittest."

ECONOMIC WORKSHOP OUTPUT.

By W. E. Hall.



IT is odd, but yet a fact, that to the majority of people the payment of a lump sum seems larger than when it it is divided into a number of payments of very small amount each, even when they are the same in the aggregate. It is in this way that we turn our backs to the leaks in cost of manufacturing operations. Many a plant has proved an eventual failure by attempting to nurse the surplus rather than by increasing the investment by the introduction of labour-saving appliances. The reverse is about as common, for increased investment must be regulated by the amount of capital at one's command. There is a happy medium,—one that is not reached by guess work, but by a simple analysis of the conditions that surround every case.

When this analysis shows conclusively that a handsome return can be obtained, and the change or addition is still unheeded, the fault lies generally with him who holds the strings of the treasury bag. He is very apt to hold the view that the expenditure of a lump sum is that amount of money sunk.

On the other hand, the superintendent is crowded to reduce the cost of the product, and after giving the subject close study finally sees a way of doing so, but he must have additional facilities which means an outlay of money and there the matter is apt to end. Competition becomes more severe, and the management is again called upon to exercise its ingenuity to bring about the desired result, when the policy of the finance department is even less disposed to go to any outlay of money.

The question of the advisability of installing new machinery should be decided upon its merits. If the reduction in the cost by the improved appliances can be shown to represent a percentage of saving greater than is averaged by the plant, the additional expenditure is justifiable. Some of our pessimistic friends will argue that the increased output will be more than the demand will warrant. The fallacy of this argument has been frequently and conclusively shown, for the decreased cost results in a corresponding increased output which eventually reduces the cost to the consumer and in that way increases the consumption.

The superintendent of one of the largest works in Belgium is known to have remarked in one of his recent trips to the United States that "it is not the first cost of American appliances that concerns us most, but that which will give the greatest output. The time has come when we must recognise this." The necessity for the better facilities was brought about, it was claimed, by the tendency towards higher rates of wages and the additional output which must be obtained per man. The rate of wages does not concern us, but the output in proportion to the wages paid and the fixed charges are the points to which attention is directed.

In all instances care should be taken to see that the expenditures are such as to give the greatest return. It is not by any means a difficult matter to be carried away by "fads" and to conclude that by their use great saving is to result, while really the contrary may be found on actual test. There are features which facilitate rapid operating, such as

the speeds of cranes, convenience in handling mechanism, the avoidance of belt shifting, as in direct electric-driven machines, where it is next to impossible to more than approximate the saving that will result by their use. A practical test is necessary to determine their efficiency with any degree of certainty.

Sometimes a saving is accomplished by intuition, which is simply good judgment, based on extensive experience. The cases, however, where the efficiency cannot be determined in advance, with some degree of certainty, are exceedingly few. Let us assume one that can be analysed. For instance, take the case where a certain piece of work is now being done by a machine of very limited capacity. The question that first arises is :—"Can we replace it by one that will do the same work in less time, and, if so, what expenditure is necessary to install it and will the saving warrant this expenditure?"

We will assume that a machine has been found that will do treble the amount of work in the same time as the one now used and without any increase in the number of hands to operate it. The elements that are affected by the increased output will vary with the nature of the plant, the fixed charges and the article manufactured, but they will always include the cost of handling the work to and from the machine, and of the power consumed.

The proportion which the fixed charges form of the total cost varies with the arrangement of the plant, cost of power, facilities for handling the work, general nature of the business and efficiency of the management. In many cases it will be found in about the following proportion, which will, at least, serve to show the *modus operandi* to reach the desired conclusion :—The fixed charges are assumed as 40 per cent. of the cost of the producer, and with the cost of the material taken as 30 per cent. of the whole, we get the following approximate division :—

	Per Cent.
Producer	42
Fixed charges	28
Material	30
	100

The fixed charges can be further subdivided. This is necessary to obtain the elements that would be affected by the increased output that has been assumed. They are approximately as follows :—

	Of Fixed Charges. Per Cent.	Of Total Charges. Per Cent.
Power	6.	1.68
Repairs to machinery	6.	1.68
Taxes	5.	1.40
Repairs to buildings	3.	0.84
Shop labour	40.	11.20
Other charges	40.	11.20
	100.	28.00

The additional output would not affect the producer cost, but would increase the power, taxes, shop labour and material, but not as much as in direct proportion as has been assumed. The total cost of three times the output obtained by the improved appliance would then be :—

	Per Cent.
Producer	42.
Fixed charges—	
Power	5.04
Repairs to machinery	1.68
Taxes	4.20
Repairs to buildings	0.84
Shop labour	34.60
Other charges	11.20
Total fixed charges	57.56
Material	90.
	189.56

In other words, the same product would cost $189.56 against $300 by the old method, representing a reduction in the cost of producing of 36.81 per cent. On a basis of the producer earning $3.00 a day, the cost of the product per day worked by the old appliance would be :—

Producer	$3.00
Fixed charges	1.20
Material	2.14
	$5.34

A daily saving of 36.81 per cent. of this is $2.33, or $700 per year of 300 working days. Taking the life of the appliance as ten years, at an interest of 6 per cent. on the capital invested and deducting one-tenth of its value each year for depreciation, shows that this saving would warrant an investment of $5384. Any less amount than this for which the appliance can be obtained is a saving in addition to the increased returns that would be obtained by the larger output. The results are almost

invariably obtained by a less proportionate investment than this analysis shows to be warranted.

On a basis of the cost of producer of $3.00 per day, and, for the sake of argument, we will assume a profit of 20 per cent., the market value of the output per day would be, by the old method, $7.93 at a cost of $6.34, leaving a profit of $1.59, less interest and depreciation. If, however, improved appliances are introduced that will give three times the output, and on the basis of the same market price, the value of the output would be $23.79 at a cost of $12.02, leaving a profit of $11.77 per day, less interest and depreciation. This, for 300 working days, gives $3531, from which the interest and depreciation of the improved appliances must be deducted. If we assumed the cost to have been $5384, this would give a net value of $2831 when the depreciation is figured as 10 per cent. and the interest on the investment at 6 per cent. per annum. When the increased investment is less than $5384, these two values approach each other and it is not an uncommon condition to find that the investment pays for itself in one year. It will be noted that the estimated warranted investment is based on the actual reduction in the cost of the product,—not on the basis of the increased profit that will result presuming the product is sold at the same market price. With the old method, and even assuming the 20 per cent. to be free of the interest and depreciation of the machine, the profit per year would be $477, against $2831.

This condition does not, generally, exist for any great length of time. Competition brings about a reduction in the price of the product, which must be met by those who expect to continue in the business, and to meet it requires the display of equal or even superior skill and greater ingenuity to do, if possible, a little better. In this strife the wit of commercial warriors is constantly kept at a keen edge. Before this reduction in price takes place, the plant has made good returns from its output and the financial condition has been strengthened. This puts the plant in a correspondingly better position to continue improving, which results in continued, increased strength so long as good judgment is used in the selection of the best appliances and facilities for the manufacture of this particular product. Those that first introduce the innovations are the ones that reap the greatest benefit. This is as it should be.

Another conclusion that we can draw is that in most cases it is more economical to crowd appliances to their greatest possible output, provided this is not at a sacrifice in quality of the work, or at the expense of a too rapid destruction of such appliances. The advantage of this is not only due to the saving in the cost of the product, but also to the opportunity which it offers to keep pace with the rapid development of labour saving devices. The improvements crowd so rapidly upon one another that unless this is done, better facilities are upon the market before the best has been obtained from those which they are to supersede.

The example taken above is a fictitious one, but it approximates the conditions of some kinds of manufacturing business where their nature is such as to require about these fixed charges. It, at least, serves to illustrate the importance, indeed, the necessity of the closest study of all devices of whatsoever kind that tend to reduce the cost or allow of an increase in the output. The example taken is not an exceptional one. In fact, it is not uncommon for appliances to be introduced that will give many times the output of the old contrivances, with a corresponding larger saving.

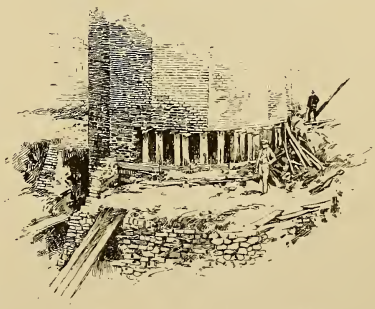
Current Topics.

WHY is it that the friction of machine bearings, like the efficiency of non-expansive steam pumps, does not declare itself? We have roller bearings, ball bearings, shell bearings, dry and self-oiling bearings, but they appear and are discussed without co-efficients of resistance. One cannot form any useful idea of the merits of a ball or other bearing except by comparison. If the co-efficient of a common solid bearing is 0.05, and with rollers or balls is 0.02, we know there is a gain of 3 per cent., qualified by the relative first cost and maintenance of the two. We speak of steam engines by a measure of the pounds of water or steam consumed; of the efficiency of pumps by foot pounds for each 100 pounds of coal; in percentage of the efficiency or losses by resistance in dynamos and motors; but not of the transmitting value of machine bearings. There is a common idea among some people that a great part of the power transmitted through bearings is lost by friction, whereas, if the real losses were known it would save a great deal of effort uselessly expended in inventing rollers and balls to evade such loss in cases where the refinement costs more than it comes to. A roller or ball bearing should always be compared with a solid one of equal cost, that is one of hard materials, carefully fitted, a ground shell of hardened steel for example, and if this were done, the difference, in so far as frictional resistance is concerned, would nearly disappear, or at least would lead to a new estimate of such difference.

PROBABLY no other kinds of power plants afford better illustrations of the tendency to concentration than some of the modern, splendidly equipped electric stations in large cities where ground area has closely approached the maximum in value and in which, therefore, economic considerations have dictated the putting of as much generating apparatus into as little space as human ingenuity would permit, with due regard to satisfactory performance. In some of these station vertical engines and boilers in large units have been installed to the entire exclusion of horizontal designs, and in others, again, the saving in ground space thus secured has been still further augmented by setting engines and boilers in tiers, one above the other, giving a ratio of horse-power per square foot of ground area

which, a decade ago, would have been thought quite beyond the limits of possibility. In probably no station in the world has this concentration been carried out to a greater degree, or to as great a one even, as in that of the Edison Electric Illuminating Company, in Duane street, in the city of New York. The ground covered by this measures 200 by 74 feet, and within this area provision has been made for nine 2500 H. P. engines, two of 1250 H. P. each and three of 600 H. P., giving a total of very nearly 27,000 H. P., with a corresponding boiler plant, or only a little less than 2 H. P. per square foot. It would seem, indeed, as though economy in space could not well be carried much further.

AN interesting, even if not altogether new, method of demolishing a tall factory chimney was recently carried into effect at Manchester, England, in connection with the Broughton Paper Mills at that place. The mills have not been in use for some time, and in order to admit of the development of the land for new streets and houses it was decided to tear them down. The chimney was octagonal in section, each of the sides measuring nearly 12 feet, and went up to a height of 270 feet, so that the problem of razing it quickly and cheaply, and, at the same time, without endangering surrounding property, became an important one. The services of Mr. Joseph Smith, a well-known "Steeple Jack," of Rochdale, were engaged to bring the structure down, and according to an account of the operation published a short time ago in the London *Engineer*, he went about it as follows :—He caused to be cut away a portion of the base on five sides, as shown in the sketch on this page, and about 5 ft. 6 in. in height, and as the cutting away of the brickwork proceeded, timber lintels or carriers were inserted and supported on props, wedges being used to pack up the bricks. This was a most difficult operation, considering the thickness of the walls and cavity to be provided for—7 ft. 8 in.—and all on the same bearing. The timbers used were of common spruce, 9 in. by 5 in., the number of props being 130, placed 7 in. apart, and perforated for the reception of resin and other inflammable substances to insure quick combustion. Whilst the work of underpinning was in progress several reports of cracks were heard from time to time, especially the day before the fall, when, to use the expression of the "Steeple Jack," the structure talked a great deal, but as the timber supports took up the compressive strain, these noises gradually ceased. When this work was completed, the spaces between the upright timbers and surrounding them were filled up with shavings, pieces of wood, coal pitch, tar, etc., and over this was poured a considerable quantity of creosote and paraffin oil. In the presence of many thousand spectators, a light was finally applied to the inflammable material, and immediately large bodies of flame



RAZING A TALL FACTORY CHIMNEY.

shot up, and smoke poured out of the top of the chimney and from innumerable cracks at various points in the columnar structure.

THE fire continued with great fury, and during its continuance, Mr. Smith was busily employed in feeding the flames with paraffin oil, at various places

where he desired the timber to be more quickly destroyed. Subsequently he ascended a short ladder which he had reared against the chimney on the north side—the fire being on the south side—and after a brief minute examination of the structure he descended, and had moved only a few yards away, when the stack quietly leaned over to the south, but it had not gone far out of the perpendicular when the portion near the base dropped into itself, and the support being thus removed, the remainder of the structure literally collapsed in telescopic form and fell in a southerly direction, the whole of the *debris* covering an area of about 25 yards long—less than half its own height—by 15 yards wide, and in the position indicated by Mr. Smith before the fire was lighted. The time occupied in the destruction of the timber supports, *i. e.*, from lighting the fire until the fall, was about seven minutes. Little noise was heard when the stack was falling, but a considerable shock was experienced as the heavy mass fell on the ground. Two tons of coal, one barrel of creosote, two barrels of paraffin oil, and about 350 cubic feet of timbers, in props and lintels, etc., were used in the work of destruction. The chimney was probably the largest and heaviest one ever brought down in this way, having weighed about 4000 tons.

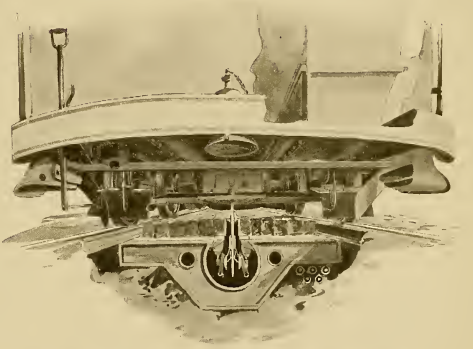
THE Board of Trade in England, which is, in a sense, an executive branch of the Government, in a late report on "Profit Sharing," says that this scheme, "as at first conceived, has been found impracticable and, where possible, has been without appreciable results." This is certainly true, and it may be said obviously so. What workmen want is the profit on their labour,—the difference between faithful and unfaithful effort; anything more is patronising and repulsive to a high-minded operator. What he wants is a measure for his work as one element in production, set off by itself, and this is easy to do, and is done, in many cases. All that is required is an estimate for the work, so wages will follow efficiency. Workmen do not furnish, nor are they responsible for, material, expense, or profit. These are affairs of owners or employers. Workmen deal with but one element out of the three that enter into production,—with labour alone. The other two, material and expense, are controlled by owners. Profit sharing mixes up these interests and is, for this reason, based upon illogical grounds.

NEW YORK'S underground trolley electric street railroad has thoroughly demonstrated its practicability by running satisfactorily throughout a winter season which has been particularly troublesome to street car traffic by reason of a number of heavy snow storms. For several years the much-spoken-of Budapest road and the Blackpool line in England stood alone as successful practical examples of this type of construction, while failures of competing designs seemed to be the order of the day, chiefly because it was the inventor who was at work, making paper designs and taking out patents, and not the engineer. To the latter the problem of building a street railroad which would take its power from an electric conductor in an underground conduit ought, long ago, have been one of comparatively easy solution, had he but taken it in hand, and the strange part of it might seem to be that he did not sooner devote himself to it. One explanation may be found in the lack of inducement which probably existed to the construction of such a road. Overhead trolley lines were cheaper to build and consequently more alluring to capital, and in some places, where these were prohibited by local legislation, the cable system had already been installed and was giving fair service. With the more and more certain promise, however, of greater economy of operation which electric car propulsion held in view, and with the ultimate design of extending the electric system to its cable sections, the Metropolitan Traction Com-

pany of New York, decided last year to take up the subject in a practical way and the result has been, as stated, thoroughly successful.

A LITTLE simplicity and common sense are of vastly more importance in a work of this kind than any amount of complex refinement, and this is very well demonstrated in the plant in question. To begin with, the road is of the simple open-conduit kind, without the mass of complicated detail which has proved so serious a drawback to the adoption of magnetic surface contact systems, flexible lip conduit systems and others of similar nature. The conduit is of the typical construction used for the cable roads. This construction was followed with the object of supplying a conduit for a cable if the electric system should prove unsuccessful or undesirable. Through the conduit on each side the contact bars are carried by hangers, and are connected laterally with feeder wires placed just under the outer shoulder of the iron conduit casting. As described in the *Scientific American*, from which the annexed sketch was re-drawn, the feeder bar is a wrought-iron pipe of 2 inches outside diameter. The pipe is inserted in 30 foot lengths and bonded at the ends with copper wire connections, bolted into the hanger slots. The hangers depend upon a porcelain cup for their insulation, the cup being corrugated inside and out, and fitting into a correspondingly corrugated cast-iron cup which receives, in its central aperture, the iron hanger rod, all being secured together by cement. To the lower end of the hanger rod a socket is bolted, and to this the pipe, in its turn, is bolted, the end of the bolt in the pipe passing through a slot 1⅝-in. long in order to provide for expansion and contraction by heat and cold The head of the bolt is so shaped that it can be introduced into the slot, when, by a right-angle turn, the bolt is secured to the pipe. The hanger bar is 1½ inches thick and 9 inches long, and the lower semi-circular socket is attached to it by a swivel joint.

THIS is the construction practically settled upon definitely, subject, o course, to minor changes if anything better can be evolved. The electrical contact apparatus, termed the "plow," is attached to the car body and is built up of sheet steel, with wood and fibre insulation, its form generally



THE NEW YORK ELECTRIC UNDERGROUND TROLLEY ROAD.

being a parallelogram. When it is remembered that the slot itself is only ¾-inch wide, it will be seen how accurately the plow has to be constructed to correspond to it in size. Its shank is 7-16-inch in thickness, giving a clearance of a little over ⅛ inch on each side. To construct the shank, two sheets of steel, ⅛ inch thick, are bolted together, and in the centre and at the ends a central shoulder and end pieces are inserted for keeping them ⅛-inch apart, thus providing two passages between them of this width, and 3 inches long, going all the way down. This shank is 9½ inches wide, and descends well into the conduit. On each side of the lower portion of the shank are carried the contact shoes. These are castings, each being 4¼ inches × 2¼ inches, and ¾-inch thick. A single shoe is used on each side. They are

carried by sheet steel springs, 2¾ inches wide, which press them outward from the plow frame. Under the influence of these springs they are pressed against the conductors with a pressure of about 7 pounds. The upper ends of the springs are clamped in place by bolts, wooden blocks and fibre sheet being used to insulate them from the plow frame. It has been found that the conduits do not accumulate dirt, and that the loss of current is not worse than on an overhead trolley. The conduit has proved to be practically self-cleaning, requiring to be swept out, perhaps, two or three times in a year, the natural flushing of the rain doing the greater portion of the cleaning. It is made, of course, self-draining. Manholes are placed along the line, never less than 250 feet apart, and at these are placed sewer connections for carrying off rain water. Over each insulator is a handhole beneath the street paving blocks, easily reached by raising a few stones.

THE great velocity at which fly wheels are driven and the consequent casualties that have become a matter of weekly report are evidence of slow evolution in providing for known wants. The sudden advent of electrical apparatus and its high speeds found people making fly wheels of cast-iron with a narrow factor of safety or, indeed, no factor of safety at all if we consider the impossibility of detecting inherent strains and imperfections in this material. No one can know the value of material moulded into form at a temperature of 2000 degrees and then cooled down to a fortieth of this temperature, nor can they judge internal structure by surface indications. The fact is that cast-iron is not a suitable material for fly wheels that are to be driven at high speed, nor is it necessary to make them of this material. There is not even the claim of cheapness in their favour if the methods of making such wheels of wrought-iron and steel were once worked out. Twenty years ago a Scotch firm, who had to make a large fly wheel for a spinning mill, riveted up a box rim, made from rolled plates and filled it with cemented masonry or "grout" and did a very sensible thing. The strength of rolled sections is tolerably well known, their integrity is beyond doubt or can be so, and all that is wanting is some ingenuity and experiment to substitute this kind of material. One reason for using cast-iron for fly wheels is to attain a section and stiffness of the arms that will, in the plane of rotation, resist the inertia and momentum of the rim. The sections of wrought-iron spokes required for radial or centrifugal strain are by far too weak for the driving strains, but this is easily provided for by diagonals as in the case of other iron structures.

WHILE writing this, an account came to hand of two steel plate belt fly wheels designed by Messrs. Thomas E. Murray and Harry E. Campbell, and built for the Albany Railway Co., at Albany, N. Y., by the Albany Construction Works of the same place. The wheels were intended for two of the railway company's large Cooper-Corliss tandem compound engines, measuring 20x36x48 inches and running at 72 revolutions per minute. Each is belted to a 500 kilo-watt electric generator. One of the wheels is now running and is giving entire satisfaction. It is 20 feet in diameter, has a 50-inch face and weighs nearly 58,000 pounds, of which total 32,000 pounds are in the rim. It has been calculated that the wheel would stand safely a speed of 250 revolutions a minute, which is equivalent to a speed of rim of over 15,000 feet, or nearly 3 miles a minute. The hub is put on the shaft in five parts and is built up of twenty steel plates riveted together. The filler of the hub is of cast iron. The disks of the wheels are each composed of two hangers of ¼-inch plates, with joints broken, and steel strips, measuring 5 inches by ¾-inch, covering the outside joints. These strips are forged at the rim ends, so as to run parallel to the face of the wheel. A cast iron

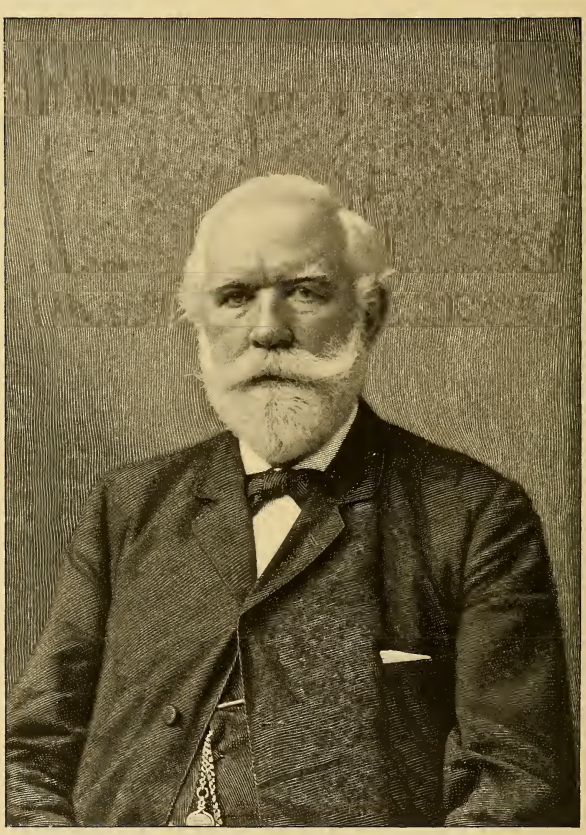
filler ring connects the disks, bolts passing through and holding disks, ring and angle irons at the rim in place. There are four thicknesses of plate in the rim, all securely riveted together.

WHY water tube boilers and those of the locomotive type are so extensively employed to drive electrical machinery, to the exclusion almost of all other kinds of steam generator, notably among these the Lancashire boiler which, in England at least, has, for a long period of years, satisfied manufacturers of almost all known commodities, has recently attracted the attention of the *Engineer*, of London. In the course of a very interesting discussion of the subject in that periodical the following partial reason is given for the circumstance in question:—"When electric light stations were first designed, the designers were in almost every case electricians, not mechanical engineers; or at least not mechanical engineers possessing any considerable commercial knowledge of the working of steam machinery. These gentlemen knew from books that high-pressure steam was more economical than low-pressure steam, in the sense, at least, that a smaller weight of the former than of the latter would give a horse-power; so it was determined that high-pressure steam must be used. But the Lancashire boiler was not deemed suitable for pressures over 100 pounds, so recourse was had to water tube boilers; and to locomotive type boilers because it was a familiar fact that on railways pressures of 150 pounds and more were regularly carried. It is no disparagement of the water tube boiler to say that the results of its adoption have not been uniformly satisfactory. It is, for one thing, peculiarly exigent in its demands for good water, and in the second it is very expensive to keep clean, and if not kept clean, the tubes split and leak. The locomotive boiler, again, is a very admirable steam generator, but it, too, has its peculiarities. It is the full consciousness of these things that has induced mill owners to resist all temptation to use any other than the double-flued or Lancashire boiler, which has been recently so proportioned that it will carry any pressure asked for. Indeed, it should be almost self-evident that if a marine boiler, 15 feet or 16 feet in diameter, can carry a pressure of 160 pounds, there ought to be no difficulty in making a Lancashire boiler of half the diameter equally strong.

"THE mistake committed by the electrical engineers has been in assuming that the boiler which made steam most readily, and was most economical in the consumption of coal, must be the best. It is just the species of error into which the non-commercial engineer is likely to fall. The truth is that coal represents but one item in the cost of making steam, and it is not invariably the most important item. The price to be paid for water is not infrequently very large; and even high-priced water may not suit either water tube or locomotive boilers. Then there is the question of wear and tear, the quality of the steam produced, and many other matters which must all be considered before it is possible to say what is the best type of boiler to put down; and all this, be it noticed, has nothing whatever to do with the qualities of the boiler regarded from the theoretical point of view. It would not be fair, however, to attribute the adoption of the locomotive type or the water tube boiler either to caprice or theoretical knowledge alone. No doubt installations were often constructed under circumstances that rendered it next to impossible to use anything but the water tube boiler. There are places in the Andes where no part of a steam engine or boiler must weigh more than 200 pounds. Everything has to be carried on mule back. There are places in great cities into which it is equally impossible to convey any large structure. For such places the sectional boiler is simply invaluable. But this scarcely suffices to explain the

favour which the locomotive type of boiler enjoys. It is not because only such a boiler can be forced, and other reasons must be found for its adoption. That it requires no brickwork, and is an excellent steam maker, are no doubt points very much indeed in its favour; but, when all this has been said and admitted, we have still to face the fact that for places where large demands are made for steam, day after day, nothing is so popular as the Lancashire boiler, or its modifications."

CONCERNING the much-discussed question whether wood, charred by long-continued contact with hot steam pipes, and thus brought into a state in which even a slight touch will reduce it to powder, will ignite from any cause except actual contact by spark or flame from an outside source, Mr. Edward Atkinson, president of the widely known Boston Manufacturers' Mutual Fire Insurance Company, cites an interesting example from his own experience. He says: "Having had occasion to test heat retarding substances on my own behalf, I once obtained some sections of beautifully prepared wood pulp, in slabs of 1½ inches in thickness and of a very porous quality, which are made use of in the construction of refrigerators. My purpose was to determine whether or not such slabs could be used to prevent the escape of heat from a lamp oven. I therefore raised the heat of my inner oven, which is a tight iron box, 1 inch distant on all sides from an outer case made of vulcanised and very solid wood pulp, to a little under 400 degrees F. In the center of that inner oven, isolated from any metallic contact with the walls, I placed one of these slabs and there left it, subject to heat at less than 400 F., for about one hour. I then removed the front of the outer oven and opened the door of the inner oven, letting a very quick and large supply of fresh air into the chamber in which the oxygen had probably been, in part, exhausted by subjection to the hour's heat. The slab of wood pulp had turned from pure white to dense black, having been converted into very porous charcoal. In less than a minute after the fresh air was let in it took fire and burned to ashes before my eyes. I then repeated the experiment with the same result. Four hundred degrees F. will be developed by a pressure of steam of 238 pounds per square inch, but the same carbonisation ensues by lapse of time even at boiling heat or 212 degrees F." The conclusion to be drawn from this is evident.



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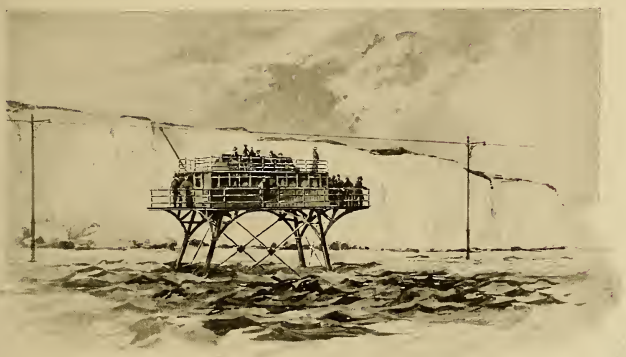

THE CAR AT HIGH TIDE.

A NOVEL SEASHORE ELECTRIC RAILWAY.

By Magnus Volk.

THE idea of running a self-propelling car on a railway submerged in the sea,—decidedly a unique one,—has been carried into practical effect at Brighton, England, where a line, operated in that manner, has been built as a means of affording visitors to that resort pure sea air and practically a short voyage without the discomforts of seasickness, and also as a means of opening up the views of the bold sea coast there, between the terminals of the line.

The project originated with the author and parliamentary powers for its execution were obtained in 1893. The actual work of construction was commenced a year later, in June, 1894, the interval having been occupied in securing the necessary licenses from the Board of Trade, the Crown, and the Corporation of Brighton. The line commences at the eastern end of the Brighton Electric Railway and extends a distance of three miles to the village of Rottingdean, a favourite summer resort. There a small iron pier has been erected for the cars to run alongside,—

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ALONG THE LINE AT LOW WATER.

the pier being available also for steamer traffic and promenading. At the Brighton end of the line an iron jetty has been erected and a building containing commodious waiting-rooms and offices was built on it.

The coast is bold along practically the whole distance, with chalk cliffs varying from 60 to 120 feet in height, and as the rails are laid a considerable distance from the shore, a fine view of the coast is obtained. The rails rest on concrete blocks, made *in situ*, about three feet apart, mortised into the sound rock, the height of the block varying with the irregularities of the shore. A shifting sand of very moderate depth covers the rock in places, but the rails were laid sufficiently high to prevent any trouble from accumulations on them. The steepest gradient is one to 300, and the radius of curves, 40 chains (2640 ft.).

The line consists of four rails (54 lbs. per yard) laid as two tracks of 2 feet 8½ inches gauge, spaced 18 feet between the outer rails, thus giving an effective gauge of 18 feet, this being rendered necessary to give the required stability to the cars. The rails are secured by

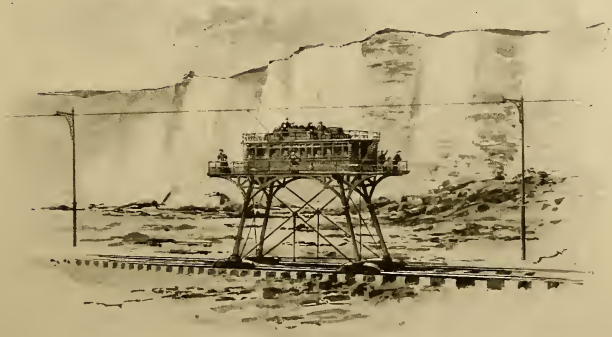
steel clips and bolts, the latter being embedded in concrete. Oak blocks, through which the bolts pass, are placed between the rails and the concrete blocks. Tie rods are also used every 10 feet on the straight, and every 5 feet on the curves, and heavy angle fishplates are used for the rail joints, the rail being in 30-ft. lengths.

The depth of water over the rails at high tide is 15 feet. Although the most violent gales experienced for many years occurred during the winter of 1894–5 no damage whatever was done to the permanent way, so the fact that it possesses ample strength to resist the force of the sea has been demonstrated in a satisfactory manner, and no accumulation of seaweed, or other matter, has taken place at any time.

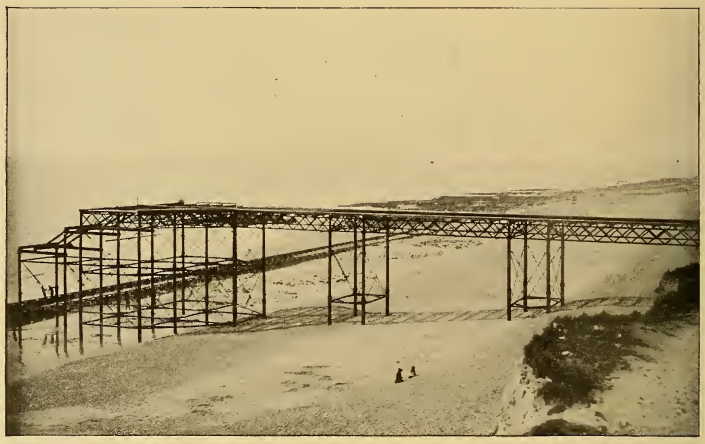
The car, which was built by the Gloucester Railway Carriage Company, is a structure on 16 wheels, each 33 inches in diameter, carrying the passengers at a height of 24 feet above the level of the rails. The four main legs are tubes of drawn steel 11 inches in diameter. At the bottom of each leg is placed a bogie truck, having four wheels, the outside of the bogie being shaped like an inverted double-ended boat to facilitate its passage through the water, and also to remove any obstructions from the rails. The four bogies are firmly held together by steel tubular struts. The wheel base is about 28 feet and with the already mentioned effective gauge of 18 feet, gives great stability.

The tops of the main legs are firmly built into lattice girder work carrying the deck, and the whole structure is firmly secured by cross ties. It is of greath strength, although offering but a small surface to the force of the waves. The main deck appurtenances and erections are carried out exactly as if for a steam yacht, and measure 50 feet in length and 22 feet in width. The railings round the deck are of iron with a wooden top rail and wire netting. An ample supply of seats, with reversible backs, is provided to enable passengers to face the direction in which the car is going.

The centre space of the deck is occupied by the saloon, a structure 12 feet wide by 25 feet long, provided with plate glass windows all round and a large central ottoman, fitted with a box between the backs in which are placed palms and flowers. The centre of the ceiling is occupied by a stained glass dome and the interior decorations are carried out in a simple but effective



THE CAR AT LOW TIDE.



THE LANDING AT ROTTINGDEAN.

A VIEW OF THE CAR.

manner. The roof of the saloon is railed round and forms a promenade deck, seats being placed over the glass dome and over the centre of the saloon. On the lower deck is placed the controlling apparatus for driving and stopping the cars. The total accommodation is for 100 to 150 passengers. As the journey is short and will be undertaken more for the sea air than for quickly making the trip, the speed is kept between six and eight miles an hour.

The driving machinery consists of two 30-horse power electric motors, placed vertically immediately over two of the main legs, one on each side of the car, the shafting being carried down inside and communicating with toothed gearing which actuates the wheels. The brakes are worked by rods passing down the remaining two legs. The current, at 500 volts, is conveyed to the car by means of a trolley pole and overhead wire, the latter being carried on handsome steel poles.

Mr. St. Geo. Moore, of Westminster, was the engineer, in conjunction with the author, the work being carried out under the latter's supervision.

While at St. Malo, in France, there is a structure which is pulled across the harbour by means of a chain, over a distance of about 110 yards, the line here considered is essentially different in design and construction and stands alone as a sample of original railway engineering. Owing to tidal difficulties the work had to be carried out in sections, and most of the material had to be lowered over the face of the cliff.

THE CAR INTERIOR.

The undertaking was strongly supported by Mr. Edward Overall Bleacky, Mr. J. J. Clark, J. P., and Mr. R. L. Pope, J. P., all keen business men without whose help, both financially and otherwise, the line could never have been completed.

WATER WORKS MACHINERY.

By Charles L. Newcomb, M. E.

"THE Moss-covered bucket which hung in the well" is typical of water works machinery in one of its simplest forms. Its very existence teaches man's superiority over circumstances, for while Nature says that water cannot run uphill, man insists that it shall. The counterpoise, an addition by some unknown genius, by balancing the parts and distributing the work so that all the labour will not come on the up-stroke, involves an important principle without which many more elaborate machines would fail, and the old wooden rod to which the bucket is attached is such a beautiful combination of lightness, toughness and strength that nothing better has yet been found for the long "sucker-rods" of modern deep well pumps. For positive action, too, no pumping engine has less slip than this primitive bucket when once fairly started on its stroke.

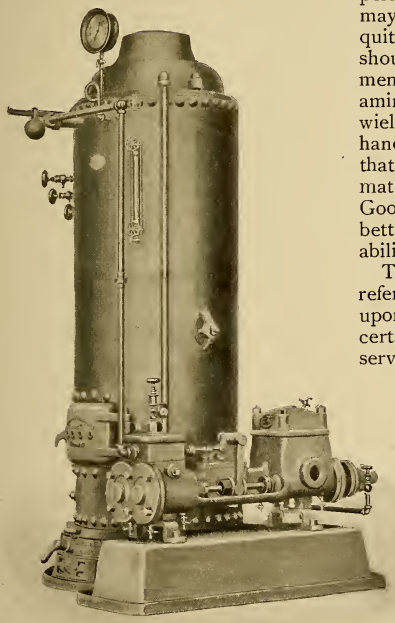
Water is recognised as one of the essentials of daily life. We are familiar with the workings of the gigantic machinery of Nature by which vapours are raised from the ocean, condensed into clouds, collected into rain-drops, brought to the earth by gravity and forced onward through rivulets and rivers to the lower level again. Somewhere in this perpetual series of operations is introduced the machinery of man, and as water is essential to life in nature, so the control of this supply is necessary to the life and growth of civilisation.

If the relative levels of the place of habitation and the surrounding country are such that by simply arresting or diverting the supply it can be made to flow to the desired point, we have the "gravity system." If the supply has fallen below the desired level, but is abundant and still moving toward a lower point, we have the features favouring a power pumping plant in which the force derived from the fall of a large body of water drives a small portion of it to the necessary elevation. If the quality of the supply is satisfactory, but the location demands the application of some outside force to make it available, we have the conditions usually requiring a steam pumping plant. The gravity system, as it requires only fixed parts, such as dams, wells and piping, and no machinery, is not within the scope of the present discussion. Steam and power plants, in the order of their capacities, will receive consideration.

Suppose for the first problem that we have a group of houses, to be supplied from a small stream, flowing through a ravine, a hundred or a hundred and fifty feet below. This requires as small a plant as can be properly designated as a water works, but, if suitably arranged, it presents some instructive features. A serviceable steam plant would be a small duplex steam pump and a vertical boiler, compactly arranged on the same base. With a pump having 6-inch steam cylinders, 4-inch water plungers and 6-inch stroke, and a multitubular boiler—about 30 inches in diameter and 6 feet high, the

apparatus would readily deliver 50 gallons of water a minute. The maximum capacity is largely in excess of this, but economy in the operation of the boiler and the durability of all parts will be increased by allowing generous proportions.

The vertical style of boiler occupies small space, and insures a free draft, and the circular fire-box requires less skill for economical firing than any other form. The pump exhaust is usually carried to the stack to improve the draft. The grates in this style of boilers are always provided with some dumping device to facilitate cleaning. The convenient arrangement of this slight detail will add much to the comfort and morals of the attendant. At a slight additional expense some simple form of shaking grate can be secured, which here bears the same relation in utility to the plain grate as in domestic economy. The duplex style of pump is a model of simplicity. Two steam pistons are directly connected with their respective plungers and the steam is distributed by plain slide valves, operated by the most simple mechanical connections with the piston rods.



A DUPLEX PUMP AND VERTICAL BOILER COMBINED.

Having selected a suitable apparatus it should be provided with an appropriate house. The compact arrangement of parts already mentioned will permit an inexpensive structure, but it may be remarked that, contrary to a quite prevalent notion, the building should not fit the machine like a garment. There should be space for examining the pump, taking out the rods, wielding the poker and storing and handling the coal. It may also be said that a pump is not like photographic material, to be kept from daylight. Good light will secure better care, better lubrication and increased durability.

The exact location of the pump, with reference to the supply, will depend upon the details of the situation, but certain general principles must be observed. The suction lift should be as small as possible, for, as the greatest theoretical suction lift cannot exceed 30 feet, and is practically much less, it is obvious that a depression of the pump level through this slight range will not add appreciably to the total forcing height, but will materially assist in giving to the pump an abundant supply.

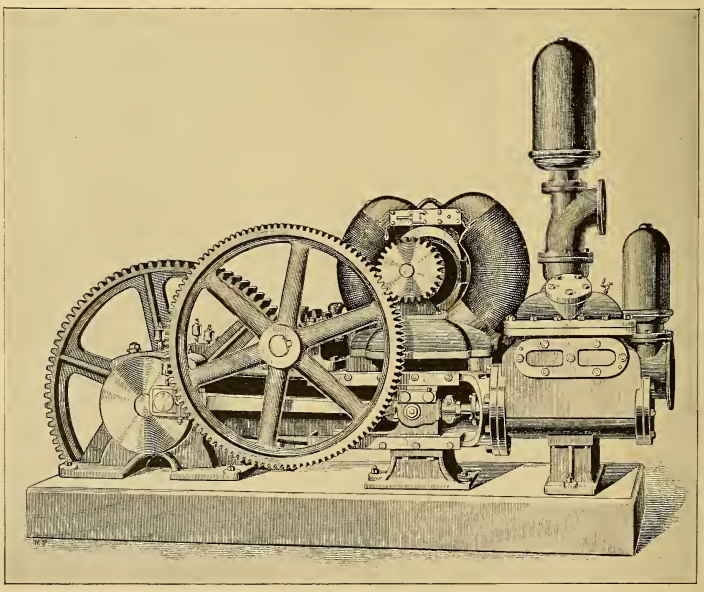
If it be found necessary to bring the suction supply through piping for some distance directly to the pump, this pipe should be of ample size, and have as few bends as possible. Three-inch pipe, to match the usual suction opening on the pump, is a proper size for ordinary lengths, but the resistance due to friction in the pipe adds practically nearly a foot to the suction lift for every hundred feet in length of pipe.

Often when the supply is not convenient to the pump-house, the water may be brought by natural flow, through drain tiles, to a small well, more favourably located.

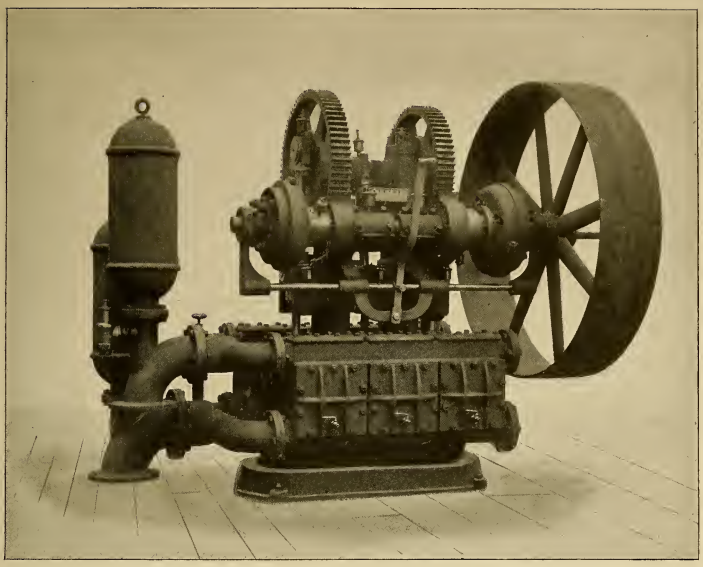
This point of frictional resistance should also be considered in planning the discharge piping. The size is not fixed so absolutely as with the suction, for we have a pressure to be produced by the pump, instead of the fixed atmospheric pressure at our command. But the best proportions, in both small and large plants, should have due attention.

To allow an unnecessary margin in the size of pipe will add needlessly to the first cost. To go to the other extreme and so reduce the size that a heavy increase in the constant load upon the pump will be produced, will make a saving in the cost of pipe, but the cost of excavation will remain the same and the running expenses will be permanently increased. Between these limits the best selection to meet a given case can be readily made when the principle is understood. Most of the trade catalogues relating to pumps and piping, give tables by which the friction for various capacities, sizes and lengths may be readily estimated.

In the arrangement of the discharge piping one of the requisites is a storage tank, interposed between the main delivery and the service pipes; otherwise, the pump must be kept in constant operation and even then there would be annoying fluctuations, according to the varying demands. This tank should, of course, be so located that the service pipes will be filled by gravity. The capacity should be such that the entire twenty-four hours' supply can be pumped within a reasonable working day or less. A simple float and signal arrangement can be used to indicate the water level in the tank.



ELECTRICALLY DRIVEN PUMP. BUILT BY THE KNOWLES STEAM PUMP WORKS, LONDON AND NEW YORK.



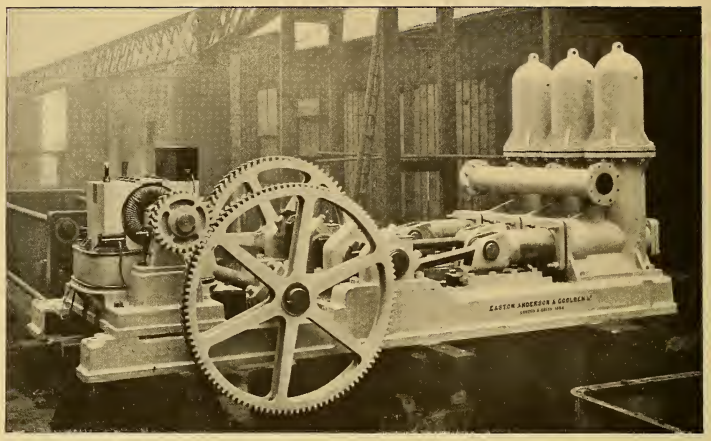
DOUBLE-ACTING TRIPLEX POWER PUMP. BUILT BY THE DEMING CO., SALEM, OHIO, U. S. A.

In the discharge pipe from the pump, and near to it, should be placed a serviceable, free-opening check-valve. This will automatically retain the water when the pump is stopped or opened for inspection, and, when the pump is working, will prevent any pulsation in the water column from reaching the pump.

For a small power-pumping plant we will suppose the situation to be similar to that just described. We will take the same group of buildings to be supplied, and the ravine far below it, through which flows the stream of water. But let us suppose that this stream has a volume largely in excess of that required on the heights above, and that other conditions are such that the power of this stream can be utilised for pumping. It is evident that such an arrangement would effect a saving in running expenses, as no fuel and but slight attendance would be required. The difficulty is that conditions favourable to power-pumping are more rare than those simply providing a sufficient quantity of water to supply the pump.

Undoubtedly the simplest form of power pump, if we may use the term so broadly, is the hydraulic ram. This familiar piece of mechanism is so limited in capacity that it cannot be termed a water works machine, but it is proper to say, in passing, that the apparatus may sometimes be used to advantage when the demands are very small.

It acts upon the principle that when the power stream is allowed to flow through a long pipe, terminating in a valve, capable of closing by the force of the current, but normally held open by a weight, this current will gradually acquire such velocity as to close the valve. The sudden recoil, thus produced, forces a small quantity of the water through a suitable valve into the delivery pipe. The escape valve then opens again and thus the operation is continually repeated. The es-



ELECTRICALLY DRIVEN THREE-THROW PUMPS. BUILT BY MESSRS. EASTON, ANDERSON & GOOLDEN, LTD., LONDON.

caping water is expended in performing the work, and the water forced upward by the repeated pulsations represents the work done. There are no working parts, except the valves, and no attendance whatever is required.

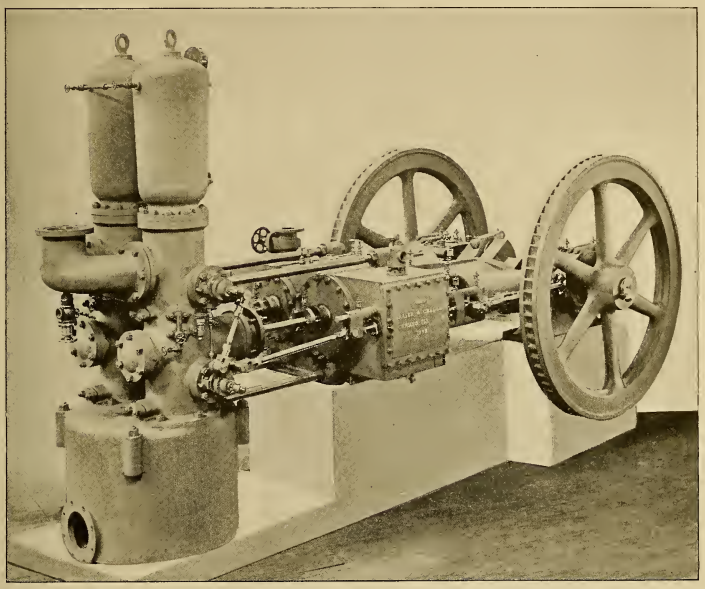
In a regular power pumping plant there is usually a turbine water wheel as the motor, and a pump consisting of an arrangement of water cylinders, pump plungers and valves, working on the same principle as the water-end of a steam pump, although often differing considerably in details, to adapt it to the special service. Between the pump and the wheel are suitable connecting rods, cranks, shafts and gearing. For small capacities the triplex style of power pump is a serviceable form. It has three vertical, single or double-acting plungers and three cranks, set at 120 degrees with one another, are directly connected by suitable rods to the three plungers.

Some of the advantages of this style of pump are that the successive action of the three plungers gives a very smooth and uniform delivery; the plunger stuffing boxes are external, easily reached for re-packing; and "slip" or leakage past the plungers is impossible.

In steam plants of much larger capacity than that which has been described, it might be supposed that the same style of machinery could be used by simply increasing the size of the various parts. But, practically, a point is soon reached where the question of steam economy becomes important. A plain duplex pump contains the simplest and least number of parts possible for performing the work. This simplicity of construction is of the highest importance in a small plant. But with one set of steam cylinders and no fly-wheel, it is necessary to admit steam to each cylinder during the entire length of the stroke in order to maintain the motion. In beginning the return stroke, this cylinder full of steam, at nearly boiler pressure, must be exhausted to the atmosphere and its expansive force thrown away. In a steam engine the admission of steam ceases early in the stroke and the remaining work is done by the expansion of the steam and the momentum of the fly-wheel.

There is a way of using the steam

expansively by the addition of another set of cylinders and yet retaining all the other features of the direct-acting pump. This style of construction gives us what is known as the compound duplex pump. This is exactly like a high-pressure pump, except that the steam, after being used in the smaller cylinders at the end, next passes to the larger cylinders instead of exhausting to the air.



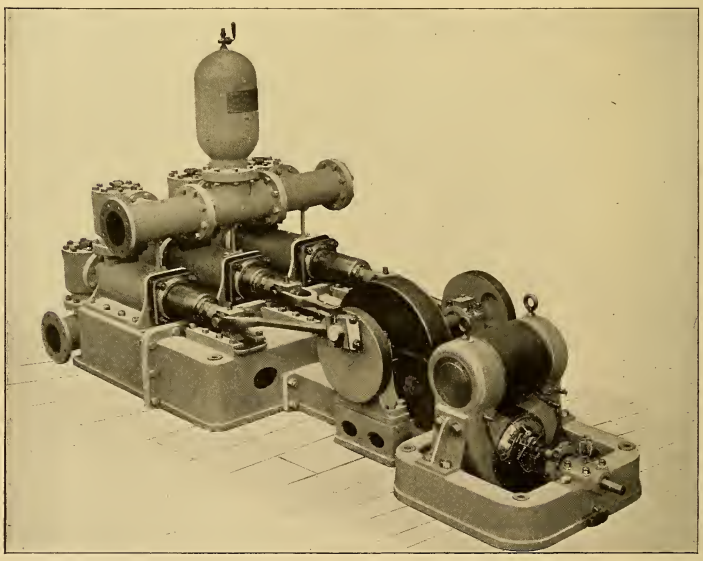
COMPOUND RIEDLER PUMPING ENGINE. BUILT BY MESSRS. FRASER & CHALMERS, ERITH, ENGLAND, AND CHICAGO, ILL., U. S. A.
Cylinders 11¼ and 18½ inches. Stroke 14 inches. Capacity 800 gallons a minute at 200 revolutions.

At each stroke the smaller cylinder is filled from the boiler and the larger cylinder is filled by the expansion of the steam exhausted to it from the other end of the smaller cylinder during the movement of the piston. With the pressure on the larger piston there is at the same time a back pressure upon the smaller piston, but there is such a great difference in the areas of the two that the net result is a forward impulse, combining with the force of the direct steam in the smaller cylinder, as both pistons are attached to the same rod. As the increased power, due to the low pressure cylinders, is secured without any increase in steam consumption, which is that required to fill the high-pressure cylinders, more work can be performed with the same quantity of steam when used in this way.

The tendency to condensation is greater when the cylinders are compounded, because the expansion occurs in them, and the increase in volume produces a decrease in temperature. Added to this is the cooling of the cylinders by radiation. The latter loss may be diminished by the use of some form of plastic covering as a non-conductor upon the cylinders, which is

usually surrounded by an ornamental casing of Russia iron or wood.

A compound pumping engine with 8 and 12-inch steam cylinders, 7-inch water plungers and 10-inch stroke, has, at ordinary speed, a capacity of from 200 to 300 gallons per minute, and it will readily deliver this quantity, through suitable connections, to an elevation of 150 feet. By varying the proportions of steam and water ends the best size for any given pressure can be selected. Following the same general design, but increasing the size of all parts, a larger capacity may be secured. This plan of steam economy, by the addition of low-pressure cylinders, is the first step in this direction.



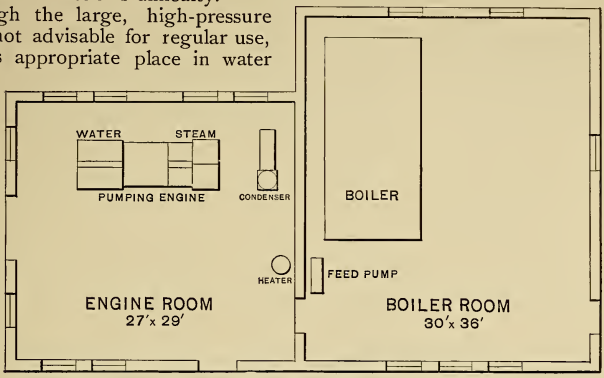
ELECTRICALLY DRIVEN PUMP. BUILT BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, ENGLAND.

Two regulating devices which are frequently used on small pumping engines may be properly mentioned here. Pressure regulators usually have a piston, acted upon by the water pressure in the discharge main, adjustable springs to determine the pressure at which the piston shall move, and connections from the piston to a steam throttle upon the engine. Any variation in water pressure will, therefore, make a corresponding change in the steam supply and, consequently, in the speed of the pump. Thus, a fall in water pressure will produce an increased speed of the pump, a larger delivery of water, and tend to increase the pressure. When this increase is accomplished, the regulator will act in the opposite direction and reduce the steam supply. These movements of the valve take place constantly and automatically and are designed to preserve an even pressure in the water mains. When properly arranged, such devices effect a saving in steam and improve the service.

Speed regulators guard against the increase of speed in the pump beyond a safe limit and keep it running at any

speed at which the apparatus may be set. By a sudden fall in water pressure, either with or without a pressure regulator, sufficient load might be removed from the pump to make it start off at a dangerous speed. The speed regulator is designed to meet this difficulty.

Although the large, high-pressure pump is not advisable for regular use, it has its appropriate place in water



PLAN OF A SMALL MODEL PUMPING STATION.

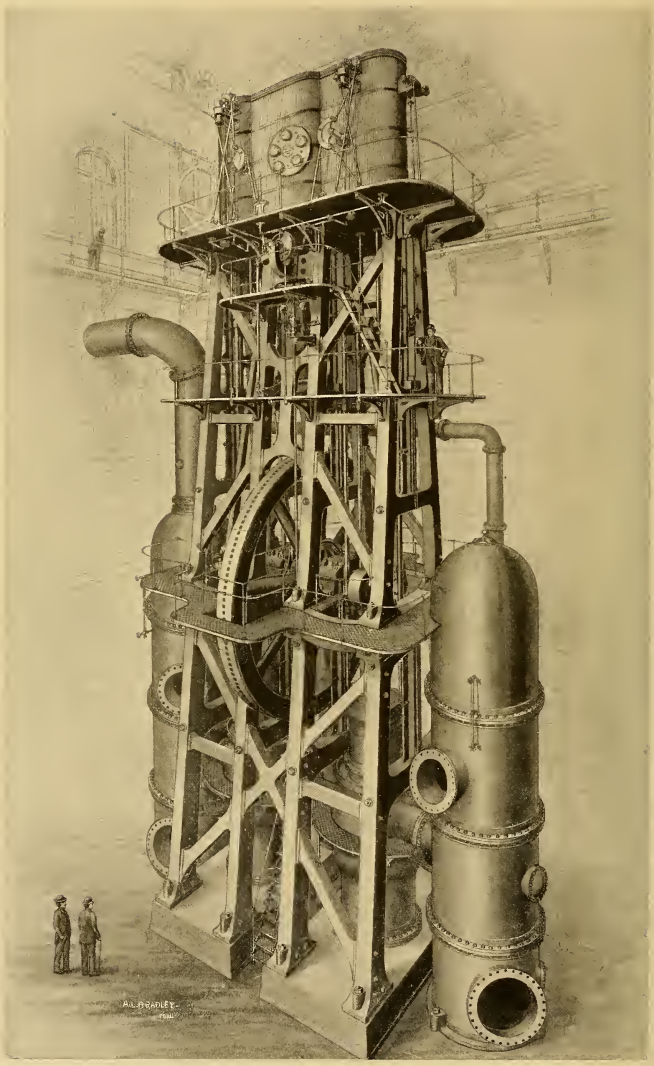
works service. If, for the ordinary service, one compound pump is needed, and a size is selected having a fair margin in capacity to provide for future increase in demands, the next thing necessary is to provide for emergencies.

Growth of the village is gradual, and by beginning with a pump, operated at very moderate speed, an increase of fifty per cent. in capacity can be made without further outlay for machinery. But the future growth is usually so certain that it is wise to provide space in the pump house for a second pump.

In this extra space may be placed a high-pressure pump of about the same capacity as the compound. This extra pump would not involve the outlay required for a duplicate compound, and for the brief intervals when this compound pump might be stopped for repairs it would answer every purpose. This extra pump may also be run in conjunction with the other for fire-service. If domestic service is alone considered, only enough boiler pressure need be provided to supply one of the pumps, but for their combined use there should be duplicate boilers, either one to be used regularly, and the pair when necessary.

The style of boiler best adapted, everything considered, to such a plant as that just described is the horizontal return tubular. This boiler does not extend above the usual height of a pump room, requires the simplest style of building, gives fairly good results and meets the requirements of the present case. The boiler power required for this class of machinery may be found by calculating the horse-power represented by the weight of the water pumped and the height or equivalent pressure pumped against, adding twenty-five per cent. to this and selecting a boiler which will have a horse-power equal to this result, computed on a basis of fifteen square feet of heating surface per horse-power.

In arranging the piping for this plant the same rules should be observed which were suggested for the smaller outfit. There should be as light and direct a suction lift as possible, and easy bends and proper sizes for the discharge. The delivery is sometimes made directly into the service mains, but a stand-pipe or a reservoir is an important addition when the situation permits of their use. A stand-pipe is simply an enlarged storage tank and



VERTICAL COMPOUND LOW SERVICE PUMPING ENGINES. 30 MILLION GALLONS CAPACITY EACH.
BUILT BY THE EDW. P. ALLIS CO., MILWAUKEE, WIS., U. S. A.

compensates for variations in the demands. A larger storage capacity for less expense may sometimes be secured, under favourable circumstances, by a storage basin or reservoir.

A complete plant under this section would consist of the two pumping engines, one or two boilers, a small feed pump and the necessary piping. A plan view of a pump room, showing an 8″ x 12″ x 7″ x 10″ compound engine and a 14″ x 7″ x 10″ duplex high-pressure pumping engine is shown in the illustration on page 175.

A power pumping plant of medium capacity properly comes next in order. This construction can be used where there is a good water power and the water is of suitable quality for domestic supply. Where the required capacity of the pump is so large that the vertical triplex style would assume unwieldly proportions, the next step is the duplex power pump. This pump has a pair of double-acting water plungers and suitable valve chambers, plunger rods, slides, connecting rods, cranks, gearing and shafting.

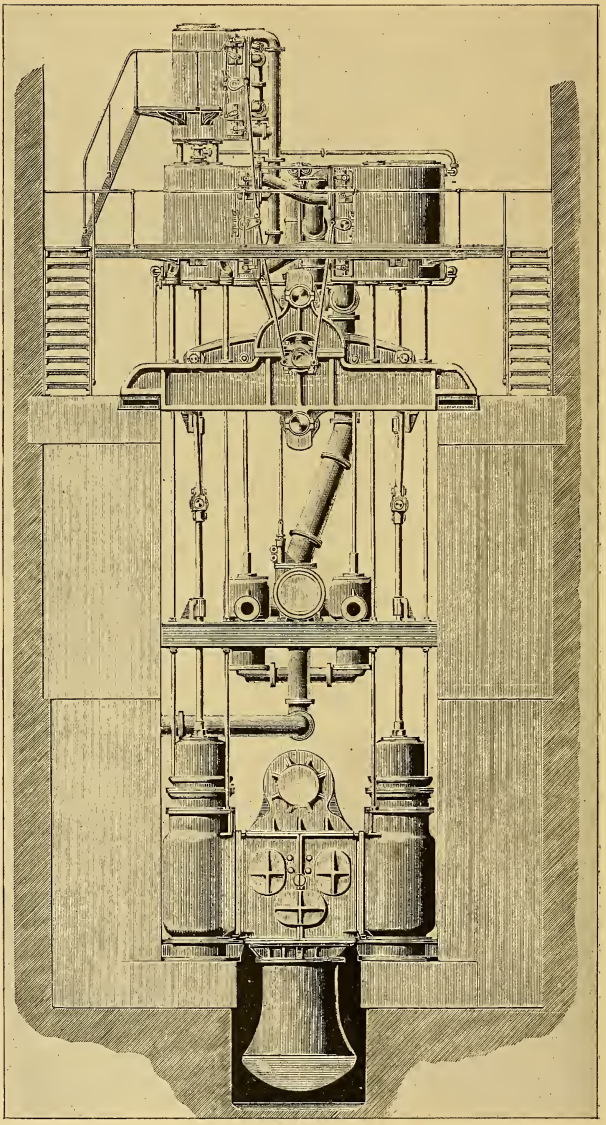
The best style of water wheel will usually be the turbine, on account of its compactness and high efficiency. The effective power of the wheel should be from 25 to 50 per cent in excess of the total load, calculated from the quantity of water to be pumped and the pressure to be pumped against. The exact margin advisable depends upon details of the service. The pump should be conveniently located with reference to the wheel and the suction supply.

In selecting the size of pump, allowance should be made for slower speed than in the steam pump and all parts should be unusually heavy; for, whereas the steam pump is acted upon by an elastic fluid which cushions the moving parts, the load in the power pump comes directly on the crank pins as they pass the centre. With proper construction and a suitable arrangement of connections, the power pump can be safely run at a higher plunger speed than is found in ordinary practice, but it is important that the special limitations of each class of machinery should be clearly understood.

The proper direction of rotation for a power pump is quite generally understood, but is sometimes overlooked. The top of the crank shaft should move toward the pump, so that the thrust and pull of the connecting rod will press the cross-head downward upon the lower part of the slides, which can be more rigidly supported than the upper portion. This is the reverse of steam engine conditions, where the driving power is the piston and where the top of the crank shaft must, therefore, move away from the cylinder in order to bring the pull and thrust downward.

In the arrangement of connections for the power pump there should always be a heavy check valve on the discharge, near the pump. When the body of water, forced onward by the action of the plungers, fails to completely follow up that which is moving in the pipe there will be a recoil, and, without a check valve, this will set back into the pump cylinders and meet the next onward impulse there with a severe shock. The pressure due to this pulsation sometimes greatly exceeds the normal pressure and, in connection with the non-elastic resistance, is a fruitful source of disaster in power pumping plants. But by the use of a suitable check valve, which arrests the backward tendency at the outset, this difficulty is entirely obviated. Cut or planed gearing should be used for power pumps. This can now be secured at so slight an advance in cost over rough cast gearing, and the smoothness of running is so much improved by its use, that there seems to be no excuse for crude substitutes.

A condition of quite frequent occurrence in power-pump service is that in which, for a portion of the year, there is an abundant supply of water for power purposes, but at certain seasons it is so reduced that, while there is enough to supply the pump, the power must be obtained elsewhere. The addition of either a separate steam pump and boiler, or a steam engine and



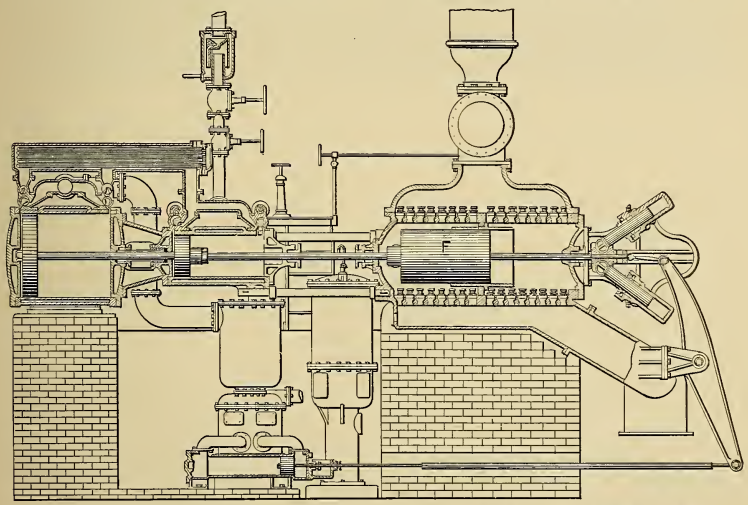
WORTHINGTON TRIPLE EXPANSION VERTICAL PUMPING ENGINE, BUILT BY MESSRS. JAMES SIMPSON & CO., LTD., LONDON.

boiler, for use during a brief period would require a more expensive plant for the temporary than for the regular service.

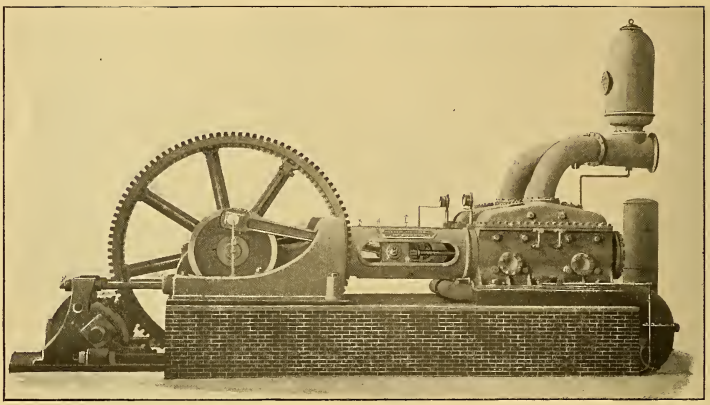
Now that electricity is in such general use for lighting and power purposes, there is a cheaper and more convenient method available. By placing an electric motor at one side of the pump and the water wheel at the other side, putting the motor in communication with some street railway or electric light circuit, and arranging a clutch at each side of the pump, or other suitable connections, either the water power or the electric power can be used, as circumstances demand, for driving the pump.

The combination of electric motor and power pump suggests that with the rapid extension of electric plants there are frequent opportunities for using to advantage an electrically driven pump where steam pumps have before been necessary. Small pumps can be driven more economically by power derived from a large engine of proper design, which is supplying this power for various purposes, than by the use of an independent boiler and cylinder, working under less favourable conditions. This fact has led to the extensive use of this plan in mining and light manufacturing and elevator work. Also, where a desirable water supply can be found near the town and a water power at a distance, a decided advantage can be gained by causing an electric wire, instead of piping, to span the distance. The water wheel and dynamo would be at the distant point and the motor and pump in the town.

When the required capacity of a steam pumping plant exceeds a million gallons a day (say, 700 gallons per minute) there is usually a desire to secure a good degree of economy in steam consumption. As the quantity of work increases, the cost of fuel becomes a large item, even under the most favourable circumstance. A reduction in running expenses will permit, profitably, a considerable increase in original outlay. The increased cost of a more efficient engine is also, in part, offset by a reduction in the size and cost of boilers, fittings and building. It will, therefore, be readily seen



LONGITUDINAL SECTION OF A HORIZONTAL WORTHINGTON HIGH-DUTY PUMPING ENGINE.



DUPLEX POWER PUMP DELIVERING 3,000,000 GALLONS A DAY AGAINST 95 LBS. PRESSURE. BUILT FOR THE LEWISTON, ME., WATER WORKS BY THE DEANE STEAM PUMP WORKS, HOLYOKE, MASS., U. S A.

that when fuel, boilers and buildings represent large values, the question of "duty" assumes an importance which it cannot have in a small plant.

As the term "duty" is extensively employed to designate the efficiency of pumping engines, it may not be out of place to define it here. As applied to a pumping engine, it means the number of foot-pounds of work that can be performed by the consumption of one hundred pounds of coal, or in other words, the number of pounds of water that can be raised one foot high, or a proportionately smaller quantity to a greater height, by use of the steam generated by this coal consumption. As the foot-pounds of work thus performed run into the millions, the duty is always given briefly as so many millions. For example, a plant shows a fifty million-duty when it performs work equal to raising 50,000,000 pounds of water one foot high with each hundred pounds of coal burned under the boilers.

In duty tests certain conditions are agreed upon. Sometimes the computation is based on the actual weight of the coal used. Sometimes there is a deduction for ashes, so as to base the test upon the combustible consumed. Often the conditions of the test assume an evaporation of ten pounds of water by each pound of coal, which eliminates the performance of the boilers and arrives at the result by a comparison of the relative quantities of feed water used and water pumped.

In computing the work performed there are also certain restrictions. Usually the load, as shown by the pressure gauge, and the quantity, according to the number of revolutions recorded by a counter, and the displacement of the plungers per revolution, are taken to represent the work, but occasionally an actual measurement or an estimate of the water delivered and its height are substituted. Unless otherwise stated, the duty is understood to be on ten-to-one evaporation, load by gauge, and quantity by counter and plunger displacement. In dictating the conditions of a test, some of the items are not of special importance, except that they be clearly defined, for if a large measure be stipulated, a corresponding decrease in the guaranteed showing can be made ; but it is desirable for all concerned that the required elements be capable of easy and accurate determination.

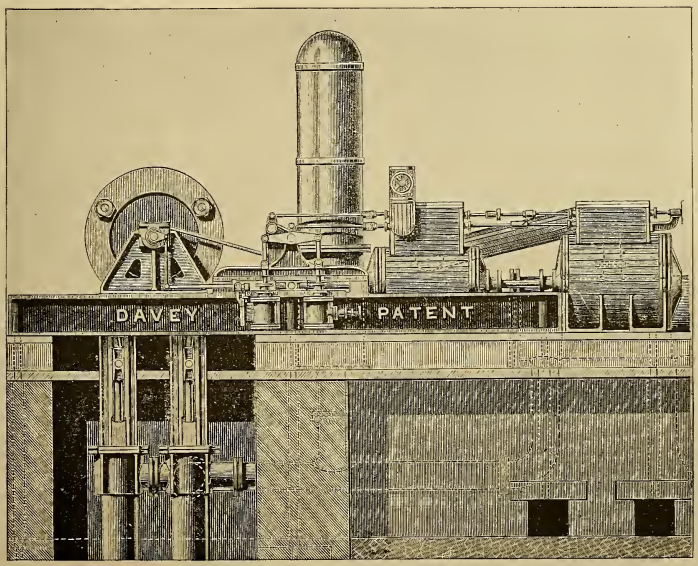
The next advance in engine con-

struction over the duplex compound style described in a previous paragraph is the duplex compound condensing pumping engine. One of these engines with 12-inch high-pressure cylinders, 24-inch low-pressure cylinders, 12-inch water plungers, and 18-inch stroke, will be taken as an example. It has a capacity, at 100 feet of piston speed per minute, of one and a half million gallons in twenty-four hours against 125 pounds pressure, with 90 pounds steam pressure.

The first difference to be noted, as compared with the plain compound engine, is that the steam, upon leaving the low-pressure cylinders, enters a condenser, in which a vacuum is maintained, so that atmospheric pressure is removed from the exhaust side of the larger pistons. This adds practically a pressure of from 10 to 12 pounds per square inch, according to the vacuum produced, while the expansive force on the larger piston and the direct pressure on the smaller piston, as in the plain compound engine, is also acting. The condenser in this plant is of the jet pattern and is attached to an independent steam pump having a 6-inch steam cylinder, a 10-inch vacuum cylinder and 12-inch stroke.

The condenser consists of a large cast-iron shell with an opening at the side for exhaust steam from the engine, and connections at the top for admitting injection water. Above the exhaust opening and below the injection opening, is a perforated copper spray plate or other similar device for spraying the injection. When the condensing apparatus is in operation, the cold injection water flows to the condenser by atmospheric pressure, is broken into numerous fine streams by the spray plate and, mingling with the body of steam, quickly condenses it.

The vacuum is produced and maintained by the great reduction in volume which takes place as the steam is



COMPOUND CONDENSING PUMPING ENGINE. BUILT BY MESSRS. HATHORN, DAVEY & CO., LEEDS, ENGLAND.

changed to water, but, in order that the condensing space may be kept clear, it is necessary that the water which collects in it should be constantly removed. This is the work of the small steam pump. A separate pump is preferable to one driven directly from the main engine, because the speed is capable of separate adjustment to secure the highest results. It can also be started in advance of the engine and the full effect of the vacuum brought to bear at the time when the maximum power is most needed. The small amount of steam required to operate it can be further utilised after leaving the pump.

It will be noticed that the cylinders in the compound condensing engine differ from those of the plain compound. With exhaust to a condenser, the area of pistons may be about as 4 to 1, while with free exhaust about 2 to 1 is the usual proportion. With the usual boiler pressure of 80 or 100 lbs. this difference is because, in the condensing engine, the expansion may be carried to any point not below the absolute pressure on the exhaust side of the larger pistons and still exert a useful effect, but in the non-condensing type anything below atmospheric pressure will produce a resistance instead of a forward impulse.

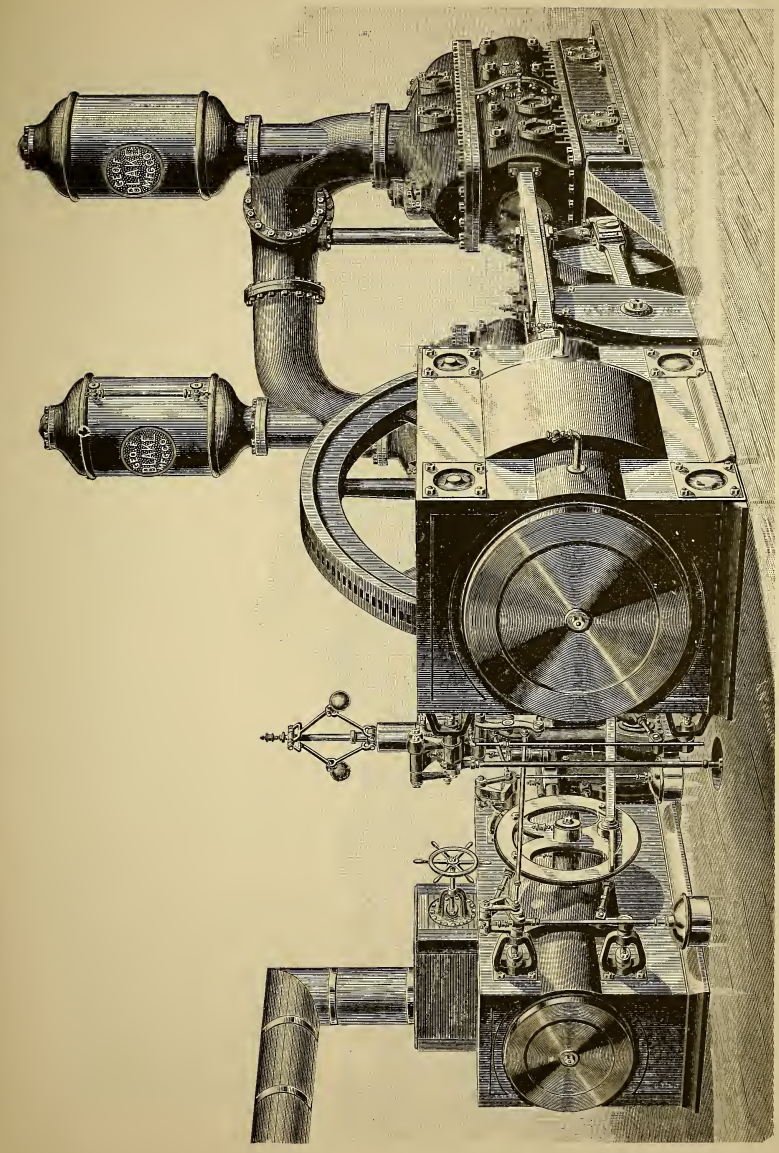
It has been stated that the steam required for driving the vacuum pump can be afterwards used for other purposes. The best way to do this is by means of a feed water heater. Sometimes the heater is connected with the engine exhaust. In a non-condensing engine such a plan may be used to advantage, but with the exhaust steam in communication with the vacuum, its temperature is so low that but slight benefit can be derived from this arrangement.

The steam from the vacuum pump is exhausted at high temperature; the greater part of this heat can be imparted to the feed water and, in addition to saving the heat, the benefit to the boilers by feeding with hot water is well understood. This heater may be of simple construction, consisting of a coil of pipe for the feed water and an enclosing case for receiving the steam. The coil should be of brass or copper, both on account of durability and for the superior conducting qualities.

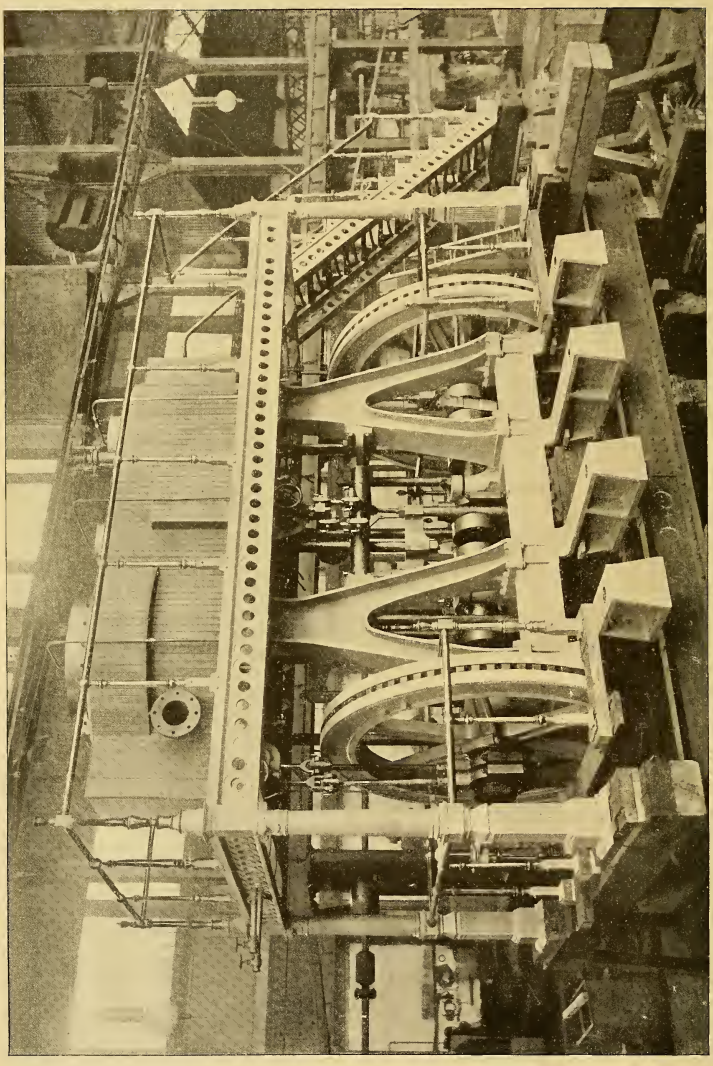
With the increasing size of the steam cylinders and the wider range of expansion, as compared with the types which have preceded, the compound condensing engine requires greater attention to the prevention of condensation in the cylinders. This is accomplished by jacketing the cylinders with live steam. Both the high and low-pressure cylinders should be cast with surrounding shells to enclose a steam jacketing space. A layer of non-conducting material outside of the jacket will reduce the radiation of heat from the jacket and allow its full effect to come upon the working steam.

As a result, there will be drier steam in the cylinders, the obstruction of water of condensation will be prevented, and, in the low-pressure cylinders, additional work will be performed by the extra expansion due to the heat imparted by the jacket. The jacket connections should be so arranged as to cause the steam to enter near the top and escape at the bottom of the cylinders, so that all the water will be constantly drained off. The heat remaining in the water from the jackets can be saved by using the water for boiler feeding.

A pumping engine of the size and construction described will give a duty of from 45 to 55 millions. The allowance for boiler capacity need not be so large in proportion to the required work as with a plain compound. With size and speed of the engine and approximate duty known, the quantity of steam required, and, therefore, the size of boilers, can be closely estimated. As an approximate rule the horse-power represented by the water to be handled may be taken, twenty-five per cent. added to allow for various losses, and boilers of this power, computed at 10 square feet of heating surface per horse-power, will be sufficient. As durability and economy result from such a margin of capacity that the boilers need not be crowded under maximum requirements, this rule is often exceeded.



CROSS-COMPOUND PUMPING ENGINE. BUILT BY THE GEO. F. BLAKE MANUFACTURING COMPANY, LONDON AND NEW YORK.



TRIPLE EXPANSION PUMPING ENGINES, BUILT BY MESSRS. EASTON, ANDERSON & GOOLDEN, LTD., OF LONDON, FOR THE WATER WORKS AT LEICESTER, ENGLAND.

Before we proceed to the consideration of steam pumping plants of larger capacity and higher efficiency, brief reference should be made to large power pumping plants. On account of the non-elastic nature of the force which drives the plungers and the peculiarities of the load, many difficulties are encountered in power pumping service, and these increase with the size of the plant, unless the principles involved are thoroughly understood. In large plants the duplex style of pump is advisable.

The gearing should consist of mortised wooden toothed gears and planed iron pinions to lessen the shock and vibration. The gears should be cast in halves to avoid shrinkage strains upon the rims. All journal bearings should be of ample size. The gear and pinion must be accurately located to make the pitch circles run together and the frame must so rigidly connect the bearings that the proper positions of the centres will be perfectly maintained. The foundations throughout must be of the most substantial character. Crank and cross-head pins must be of generous proportions to withstand the sudden strains to which they are liable. The cross-head shoes must be sufficiently large in area of bearing surface to reduce the pressure per square inch to a safe limit. Special attention must be given to the lubrication of all boxes and bearings. All tendency of the discharge column to pulsate and recoil upon the rapidly advancing body of water in the pump must be prevented by a check-valve just beyond the pump. While power pumps of one or two million gallons capacity per day have often failed by ignoring the special requirements, there is no reason why three or four-million gallon pumps, if properly constructed, should not be as durable as steam pumps of the same capacity.

A duplex power pump, designed by the writer for the water works at Lewiston, Me., U. S. A., in accordance with the principles here outlined is now on its second year of continuous operation, twenty-four hours a day, delivering three million gallons of water per day against the contract pressure of ninety-five pounds.

In the compound engines thus far considered, the cylinders have been proportioned so as to give the best results when using steam at an initial pressure of from 80 to 100 pounds. This gives a range of expansion in the compound engine not exceeding 100 pounds, and in the compound condensing engine only a few pounds additional. This is as wide a range as is practicable with the construction thus far described. In recent years, however, much attention has been given to increasing the range of expansion. The steam pressures, particularly in marine practice, have been steadily increased, with corresponding changes in engine construction. As a result, there has been a marked improvement in efficiency. The next step to be mentioned in connection with pumping engines is in this direction.

A steam pressure, in suitably constructed boilers, of 125 to 150 pounds can be readily obtained. Steam at this initial pressure, admitted to compound engines of the proportions given, would obviously result in too high an ultimate terminal pressure,—that is to say, the pressure of the exhaust from the second cylinder would be so high as to occasion great waste. To remedy this by a further increase in the proportionate size of the larger cylinders would require a greater degree of expansion in each than could be profitably performed in one cylinder. The wide variations in temperature in the cylinder at each stroke, caused by a greater expansion than from about 100 pounds, makes some modification in the form of the engine necessary for a further extension in the range.

This fact and the previous construction naturally suggest the addition of a third cylinder to the series, so that a portion of the work may be done by the high-pressure steam in one cylinder, from which it passes to a second and larger cylinder of such proportion that partial expansion takes place, and from there it goes to a third and still larger cylinder for the completion of the ex-

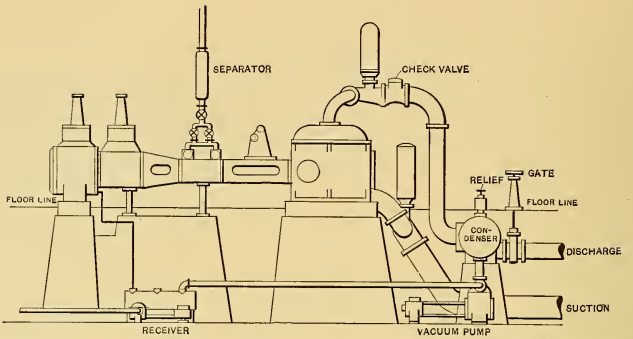


DIAGRAM OF A DUPLEX THREE-CYLINDER COMPOUND PUMPING ENGINE AND ITS CONNECTIONS.

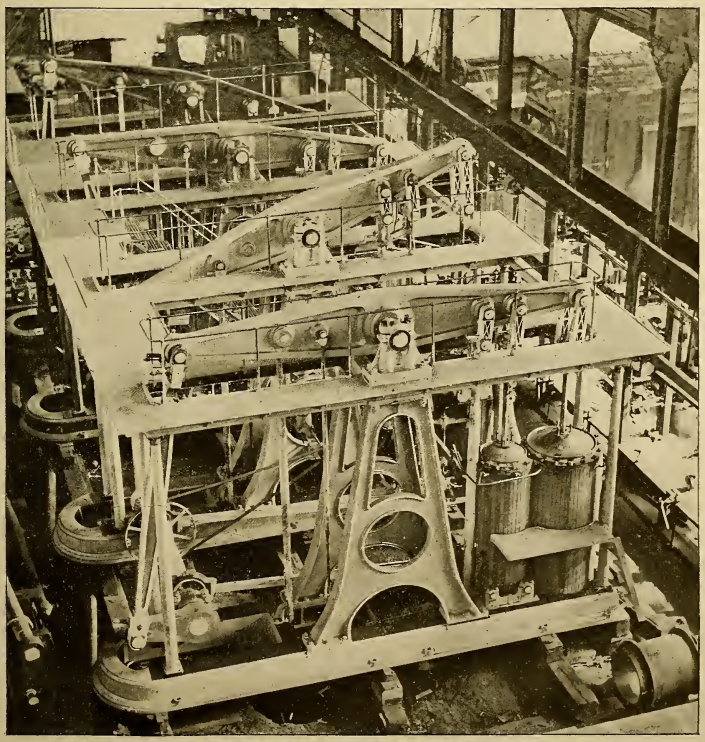
pansion. The second and third pistons both combine their forward impulse with the first piston on the same principle as when but two pistons in line are used.

In order to properly operate the steam valves without the intervention of a fly-wheel, two sets of these cylinders may be placed side by side in the same manner as with other duplex engines. This construction, in connection with suitable water cylinders, constitutes what is styled a duplex three cylinder compound pumping engine. Some manufacturers have secured still further efficiency in this class of engines by arrangements which permit a higher piston speed, a reduced clearance, and a variable cut-off for expansive working of the steam in the high-pressure cylinders. It is impossible to run the pistons as closely to the heads in a direct acting engine as with fly-wheel connections, but this point can be approached and a considerable saving in steam can be made by the use of cylindrical valves, located close to the cylinders, in place of the ordinary flat slide valves and long steam ports. All the cylinders should be steam jacketed.

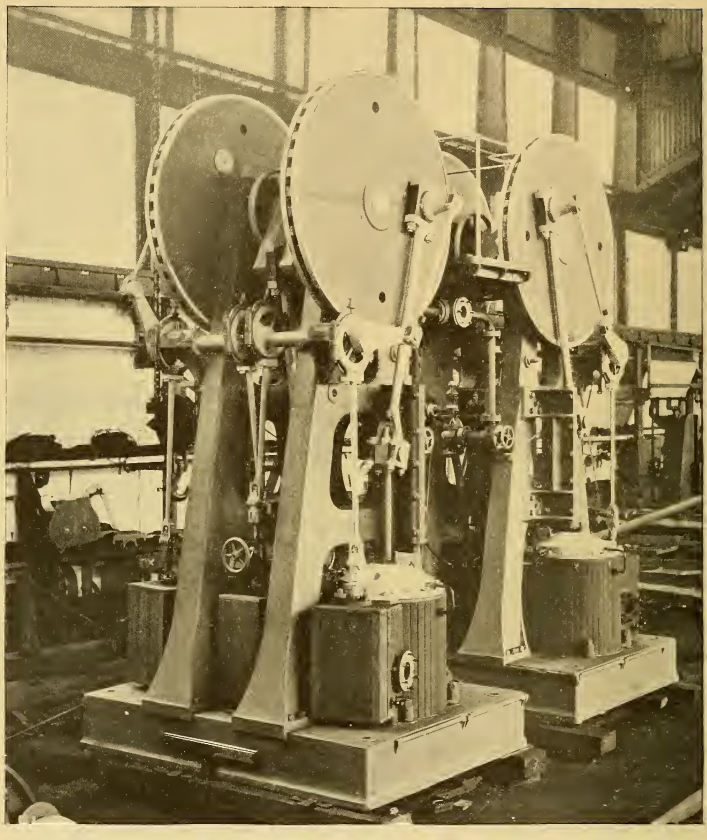
To secure the highest results from the plant, the jacket outlet should be connected with an automatic pump and receiver. This consists of a small closed tank, or receiver, connected with a steam pump discharging to the boilers, and fitted with an attachment which regulates the speed of the pump, so as to maintain the water level at a fixed point. This is, in effect, a hot-well, but the constant withdrawal of the water permits it to be of very small proportions and effects a quick transfer of the water to the boilers without loss of heat. The same receiver also handles in the most economical manner the water condensed from the engine exhaust in case this condensation is performed by a surface condenser.

As automatic tank attachments, of which the action depends upon a float, sometimes prove troublesome, it may be well to mention a desirable construction which is probably familiar to most readers. A hollow metal float is liable to leakage, and, under certain conditions, to collapse, which destroys its buoyancy. By making the float an open cup-shaped vessel, this danger is removed. With the cup attached to a lever which is counterbalanced to nearly the weight of the cup filled with water, it is evident that when the water level is below the cup the total weight of cup and contained water will be effective; but if the water in the receiver rises above the cup then the weight acting is only the weight of metal in the cup which is now surrounded inside and out by the water. Hence, by reason of the counterbalance, the cup now rises and, by suitable connections, the pump is started and removes the surplus water from the receiver.

As shown in the sketch opposite, the style of condenser advised for this grade of steam plants is a surface condenser, connected with the discharge from the engine. There is an outer case of cast iron through which the discharge water passes. Enclosed in this case, and surrounded by cold water, is a system of tubing into which the exhaust from the engine is admitted and from which the water of condensation is removed by an independent vacuum pump as shown. The steam is condensed by contact with the tubing, which is constantly cooled by the water which surrounds it. Unlike the jet condenser previously described, the cooling water does not come into actual contact with the steam. With surface condensation the water removed by the vacuum pump is much less in quantity and higher in temperature than with the jet condenser. As the work to be performed by the pump is very light, its steam cylinder is small in proportion to the vacuum cylinder. It does not approach to the proportions necessary to pump the discharge to the boilers, but will readily deliver it to the automatic receiver, where that and the jacket water are both immediately carried forward. The exhaust from the receiver pump and the vacuum pump should be carried to a feed water



TWO PAIRS OF COUPLED BEAM PUMPING ENGINES. BUILT BY MESSRS. EASTON, ANDERSON & GOOLDEN, LTD., FOR THE ANTWERP WATER WORKS.



TWO PAIRS OF THREE-CYLINDER COMPOUND PUMPING ENGINES. BUILT FOR THE COLCHESTER, ENGLAND, WATER WORKS BY MESSRS. EASTON, ANDERSON & GOOLDEN, LTD.

heater. Entrained water, and that condensed in the piping, in the steam supplied to the engine, should be taken out by a suitable separator, connected to the pipe near the engine. Separators act on the principle that gases in rapid motion can change their direction more readily than fluids, so that when steam is compelled to traverse a spiral or zig-zag course the water will be thrown out. The water extracted by the separator should also be carried to the automatic receiver, or, if sufficient elevation can be secured, it can be returned directly to the boilers.

The sketch on page 186 indicates also the proper arrangement of the water piping. The suction enters the pump room by easy bends and is attached to a special which communicates with the two water cylinders. Upon this suction special is a large galvanised steel air chamber, which prevents the shocks which would otherwise result from the rapid and intermittent motion of so large a body of water. For the same pur-

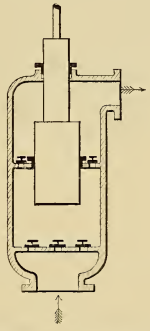
pose there is a large air chamber upon the discharge connections, as close as possible to the cylinder. Next follows the check valve, and then a relief valve, set at the maximum pressure allowable. The relief valve protects the pump from excessive pressure by opening and permitting the escape of water when the limit is passed. In a convenient location, beyond the relief valve, is placed a gate valve, with standard and hand-wheel above the floor.

The increasing size of the plant and the demand for higher steam pressure renders a change in the style of boilers advisable. In the several makes of large vertical boilers now on the market the necessary floor space is much less than with horizontal boilers of the same capacity; drier steam will be produced, there is a free draft, and this form is, at least, as well adapted to high pressures. Mechanical stokers, of which many different kinds are now available, may also be used, and form a valuable addition to a high duty steam plant.

Some of the advantages secured by mechanical in place of hand firing will result from an automatic control of the dampers. No hand adjustment of draft can approach in accuracy the service given by an automatic regulator. Instead of sudden fluctuations according to the observation or convenience of the fireman, such a regulator will be moved by slight variations in steam pressure and will promptly attend to the necessary changes in draft to bring the pressure back to the given point. Proper attention to the appearance of the grate will prevent the delivery of more fuel than the damper regulator permits to be consumed.

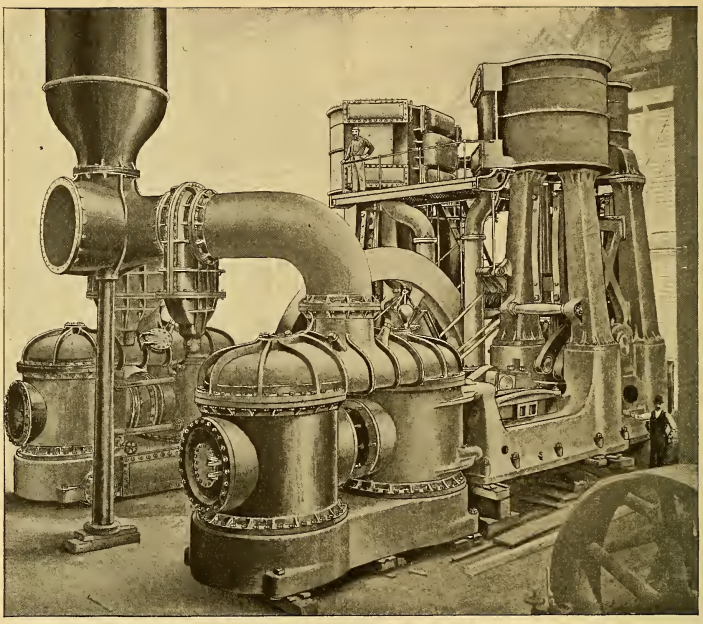
By the improvements thus far noted, the cylinders of direct-acting engines have been compounded, the condenser has been applied, steam pressure has been increased, boiler appliances have been improved, and all the heat possible has been returned to the boilers. In order to make any further marked advance, it is necessary to make some decided change in the style of the engine. The prominent feature of this change is the addition of cranks and fly-wheel. In a non-rotative engine all the principal moving parts travel in straight lines. When the steam pistons approach one end of the cylinders a confined body of steam is met, upon which they cushion. The valves are reversed at this point and the return stroke begins. The length of stroke is influenced by speed, variations in load, and adjustment of valves.

By the introduction of suitable rotating parts in connection with the reciprocating ones, several decided advantages are gained. As the travel of the reciprocating parts depends upon the throw of the crank, it is in the fly-wheel engine a fixed quantity. As the precise end of the piston travel is known, it is possible to bring the cylinder heads very close to this point and thus reduce the clearance space. As the momentum



DIFFERENTIAL PLUNGER PUMP.

of parts cannot increase the length of stroke, a much higher piston speed can be safely attained. As the inertia of the fly-wheel will continue the motion when the pressure in the cylinders decreases, there may be a cut-off and expansion in all the cylinders. Compounding by a series of two, three or more cylinders may be used in the same way as with direct acting engines, for the use of steam at an extremely high initial pressure. These cylinders may be arranged vertically or horizontally, as the special conditions may require. An automatic cut-off, controlled by a



TWIN COMPOUND CONDENSING CRANK AND FLYWHEEL PUMPING ENGINE. BUILT BY THE SOUTHWARK FOUNDRY AND MACHINE CO., PHILADELPHIA, PA., U. S. A.

governor, may be used, and all the steam valves may be of the Corliss style to reduce clearance. Thus the best features of direct-acting engines are retained, and higher speed and reduced clearance are added. As in other advancements, these changes increase the cost of the machine, but effect a saving of steam which makes the extra outlay a profitable investment.

In fly-wheel engines the water end, or pumping mechanism, is more or less separated from the steam end to accommodate special features in the engine or to place the pump favourably with reference to the water supply. If the piston speed of the engine is higher than is advantageous for the best working of the pump, there can be a beam connection which will reduce the length of stroke and, consequently, the piston speed of the pump. If the cylinders are horizontal, the form does not differ essentially from that used in non-rotative pumping engines. When the level of the supply is subject to wide variations, or is lower than it is convenient to set the engine, a vertical water end is often desirable or necessary.

Single-acting plungers are simple in construction, the stuffing boxes are external and readily accessible and when three of these plungers can be arranged to work together there is quite a uniform delivery. By enclosing the plungers so that they work through stuffing boxes at the centre, and each end enters a water chamber, each plunger is made double-acting. This plan doubles the capacity of a plunger of given diameter and a pair of these plungers gives a very even delivery of water. The water valves are arranged for convenience of access and so as to give as direct passages as possible. Air pockets, which, in vertical pumps, may

obstruct the action, must be avoided. A compact form of vertical pump which is a modification of the double-acting plungers is that known as the differential plunger pump. This has plungers which are equivalent to two plungers of different diameters, placed end to end, and moving together. One plunger has about twice the area of the other. The plunger rod is attached to the smaller part and below this is the larger part of the plunger. The smaller portion enters the cylinder through an external stuffing box, and the larger part works through an internal stuffing box or bushing. The suction valves are below the plunger and the discharge valves are usually in the partition containing the large stuffing box.

This arrangement is, in effect, a double-acting plunger, with the smaller part of the plunger acting as a plunger rod of unusal size. This rod portion occupies about one-half the volume left by the withdrawal of the larger portion. Thus, the lower end has twice the displacement of the upper, water presses through the suction valves only on the up stroke, and through the discharge valves only on the down stroke, but the flow from the upper chamber is continuous. The construction described is shown in the diagram on page 189.

In the line of still further increased economy are mechanical draft and the economiser and mechanical devices for the handling of coal and ashes. The fuel economiser consists of a feed water heater, located so as to receive heat from the furnace gases before they are allowed to escape to the chimney. The feed water circulates through tubes, between and around which the gases pass. In order to abstract as much heat as possible, it is necessary that this apparatus should be placed directly in the line of the draft. The location, arrangement and comparatively low temperature of the tubes causes a rapid deposit of soot upon them which would soon impair their efficiency. Therefore, an arrangement of scrapers is provided to automatically clean the heating surface.

Mechanical draft, secured by an exhaust fan, must be used in connection with the economiser in order to draw the products of combustion through the obstructed passages. The fan causing the draft also makes the boiler plant independent of atmospheric conditions, provides for sudden demands for steam and saves most of the cost of a chimney.

Coal and ash conveyors, driven by power from the fan engine, serve an important purpose in reducing the labour expense and improving the service. Coal may be brought from the bunkers and distributed to the hoppers of the mechanical stoker, and the deposits in the ash pit may be continually carried away by the most simple mechanical means.

In closing this review of water works machinery it may be said that no attempt has been made to enter into all the details of construction, but rather to touch upon prominent features of general interest. In selecting the machinery for a given situation, the capacity of the plant and the relative importance of present and future outlay must determine the choice. For all permanent work it is believed that the penny-wise policy is becoming less common as the difference between pumps and pumps is better understood.

MEGASS AND REFUSE FURNACES.

By William Price Abell, Assoc. M. Inst. C. E.

The desirability, if not necessity, of greater fuel economy in raising steam has, of late, helped to bring into prominence furnaces for burning all kinds of refuse, notably city refuse, the satisfactory disposal of which, in itself, has become an important problem. But the utilisation of factory wastes, outside of large cities, is of almost equal interest, and among these the refuse from cane-sugar manufacture has received careful attention by many engineers. Mr. Abell's paper, therefore, recently read before the British Institution of Civil Engineers, giving particulars of the use of such refuse as fuel and describing several furnaces adapted to handle it satisfactorily, will prove instructive reading.

THE use of megass as fuel in the manufacture of cane-sugar has, during the past few years, largely owing to the increased cost of coal, become more general; and on many estates in the West Indies it has entirely replaced coal, of which 25 cwt. were formerly required for the production of one ton of sugar. During the years 1890–94, five hundred and twenty furnaces were rebuilt in British Guiana, at a cost of about £50,000, the annual saving thus effected amounting to more than £100,000.

On the assumption that sugar-cane contains 12.5 per cent. of woody fibre, and the juice 16 per cent. of sugar, Mr. Nevile Lubbock states, as the result of many trials, that double crushing extracts 72 per cent., and single crushing 66 per cent. of the juice, leaving the green megass, composed in each case of woody fibre, water and sugar in the following proportions:—

	Double Crushed.	Single Crushed.
	Per cent.	Per cent.
Woody fibre	45	37
Water	46	53
Sugar	9	10
	100	100

Exhausted diffusion chips reach the furnace composed of 60 per cent. of water, 0.44 per cent. of sugar, and 39.6 per cent. of woody fibre.

In the old furnaces, which do not utilise the oxygen and hydrogen in the water of the megass for combustion, it is calculated that 4.83 lbs. of double-crushed megass and 5.98 lbs. of single-crushed megass are required to give the same amount of available heat as 1 lb. of Scotch coal. Sir Frederick Bramwell and Dr. Letheby, in their report on the sugar manufactories belonging to the Khedive of Egypt, state that 2.09 lbs. of sun-dried megass are equivalent to 1 lb. of Welsh coal. From 100 tons of single-crushed cane are obtained 34 tons of megass, sugar and water combined, as fuel, 8½ tons of sugar and 57½ tons of water, to be evaporated out of the juice; and from 100 tons of double-crushed cane there result 28 tons of megass, sugar and water as fuel, 9½ tons of sugar and 62½ tons of water to be evaporated out of the juice. With single-crushing, therefore, for every ton of sugar manufactured, 4 tons of refuse or megass, of which 53 per cent. is water, and with double-crushing 3 tons of megass, of which 46 per cent. is water, are obtained. This fuel, in modern, though still imperfect, furnaces, will evaporate 57½ tons to 62½ tons of water from the juice of 100 tons of cane, besides generating all the mechanical work involved in crushing the canes and manufacturing the sugar. A surplus of megass should be stored whilst the mills are working, so that it may be

possible to manufacture with it the offal products after the grinding ceases.

The results of long grinding at a factory producing 1¼ ton of sugar per hour, show that the amount of megass available per hour is 3.75 tons, consisting of 2.03 tons of fibre and 1.72 ton of water. This is burnt in five furnaces, of which two are of the type shown in Figs. 1 and 2, and three are of the type shown in Fig. 3,—4.24 cubic feet of megass being thus available for each furnace per minute; but sufficient steam is maintained with 3 cubic feet per minute. Each furnace has a grate-area of 20 square feet, and each supplies heat

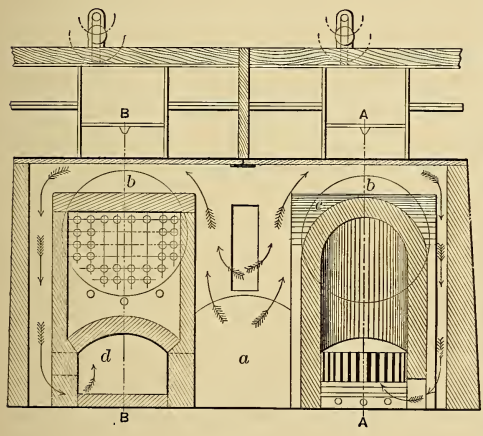


FIG. 1.

to a multitubular boiler containing 1300 square feet of heating-surface. The chimney draught is 40 feet per second, the flue temperature is 500 degrees F., and the furnace temperature is such as to melt copper and partially melt cast-iron, about 2000 degrees F.

The steam obtained from these five boilers and furnaces concentrates and purifies 9.45 tons of juice into 1¼ ton of pure yellow sugar per hour. The boiler-pressure is 75 lbs. per square inch, and the cane is crushed at the rate of 13.2 tons hourly, 3.75 tons of megass and 9.45 tons of juice being produced—the latter consisting of 1.25 ton of sugar and 8.20 tons of water and offal. In addition to extracting juice from the cane with a pressure of 250 tons on each of the top rolls, the water is evaporated, the sugar is cured, and the molasses is converted into rum and second sugar. The 3.75 tons of megass develop the requisite power without the assistance of any other fuel, the duty of the engines employed amounting to 463 I.H.P. and the heating-surface in the evaporators being 5650 square feet.

The water in megass was, until a few years ago, evaporated in the furnace and driven out of the chimney as waste steam. In some cases the megass was dried in the sun or in logies, on the theory that to employ water as fuel was to use more energy than could be realised from the combustion of the oxygen and hydrogen obtained from its decomposition. Ordinary megass, if burnt in the usual way, scarcely produces heat enough to promote its own combustion. The result of the improvements in furnaces has been that condensed steam or white smoke is seldom seen issuing from megass chimneys. Green megass may be taken to consist of 50 per cent. of fibre and 50 per cent. of free water, the small quantity of sugar and ash present being negligible. The chemical analysis of the substance is :—

	Per cent.		Per cent.
Carbon	25.00	Woody fibre	50
Hydrogen	2.78		
Oxygen	22.22		
Hydrogen	5.56	Free water	50
Oxygen	44.44		

Megass thus contains exactly the amount of oxygen necessary for the complete combustion of its carbon.

When hydrogen and oxygen exist in a compound in the proper ratio to form water, its constituents have no effect on the total heat of combustion. This would be the case with woody fibre in megass, under ordinary circumstances,

when burnt in the older type of furnace. On the other hand, in a properly designed green-megass furnace, when thoroughly heated, the water, in the form of aqueous vapour, is decomposed in passing over the highly incandescent and porous carbon of the megass; oxygen is liberated and combines with the carbon to form carbonic acid; and the hydrogen passes off partly uncombined and partly as carburetted hydrogen. The latter, in presence of sufficient oxygen and at the high temperature of the furnace, undergoes further combustion and yields additional heat by its conversion into carbonic acid and water. This is shown in practice by the fact that little air is required for a furnace after it is properly started. If the pores of megass could be impregnated with air and saturated to the required extent, each atom of carbon being contiguous to the necessary air before the fuel was thrown upon the grate, the result would differ from the ordinary smouldering combustion, and would approach that of gunpowder, which contains the necessary oxygen for perfect combustion without air. The fuel should first be gasified and then burnt, the moisture being split up and the oxygen and hydrogen used for the combustion of the carbon in the megass.

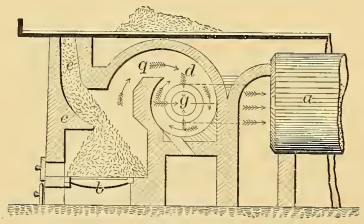


FIG. 3.

In an efficient megass furnace perfect combustion of the gases and carbon flecks should be produced, the gas being first liberated and then consumed, so that no white vapour escapes from the chimney. It should require no increase of chimney height, and should work without forced draught. The temperature in the combustion-chamber should be sufficiently high for the production of water-gas. Ample provision should be made for expansion through large and varying ranges of temperature. Furnaces have been constructed in which the waste heat from the chimney is utilised for drying the fuel on its way to the fire-box. Experiments made by the author in 1887, however, showed that with a flue-temperature of 550 degrees F., a layer of megass 3 inches thick took forty-five minutes to dry.

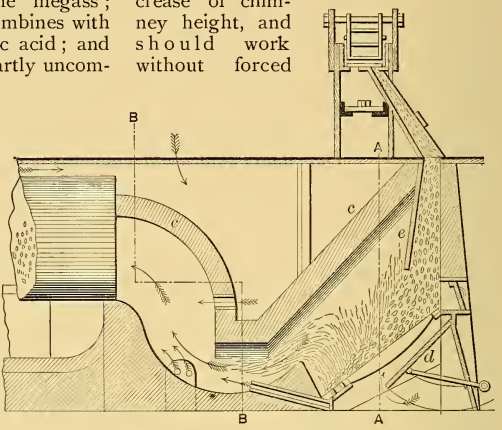


FIG. 2.

In Fig. 4 is shown the Alfred Fryer furnace, introduced in 1883 by Mr. Maurice Costa, and adopted with success in British Guiana. The grate *b* is inclined with the lowest part at the furnace front, and the green megass is introduced between the bars and boilers *a*, so that all the flames pass through and over the green fuel on its way down the drying-plane *c*. The megass is introduced at the opening *e*, and, fall-

ing on the inclined drying-plane, it gravitates downwards on the fire-bars, as that below it is burnt. The whole of the products of combustion pass up over this drying-plane and there evaporate much of the moisture of the megass. The flames then pass the feed-mouth into the combustion-

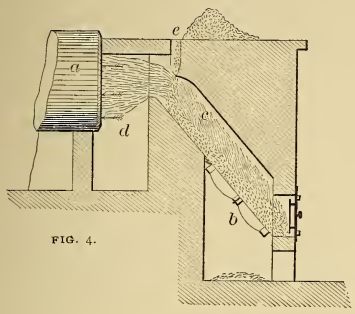


FIG. 4.

chamber *d*, and finally into the boiler. No air was observed to be drawn in at the feed-mouth, although the stream of flame was always plainly visible passing this opening, which measured 10 inches by 5 feet.

In 1890 the furnaces shown in Figs. 1 and 2 were introduced by the author. They are arranged in pairs, the air for combustion being drawn between the two furnaces at *a*, over the boiler-tops *b*, and finally over the reverberatory arches, *c c*, into the ash pit. The air is caused to pass the hottest or lower part of the fire-bars by the deflecting-plate *d*, reaching the top end of the fire-bars and entering the megass at a temperature of 300 degrees F. The check-wall or plate, *e*, regulates the thickness of megass on the fire-bars. In order to still further heat the air and facilitate the complete combustion of the gases and carbon flecks, a similar furnace, but possessing an additional combustion-chamber, was introduced and gave highly satisfactory results.

In 1892 the automatic feeding arrangements were added, with a view to reduce labour on megass platforms, to dispense with the gearing hitherto used in mechanical firing, and to give a constant and regular feed of fuel. They have proved so sensitive in practice that without any assistance they can supply one furnace with the exact quantity of megass, passing the surplus on to the next. The megass is carried the whole length of the platform by the usual rake-carrier, connected with each furnace by enclosing hoppers. Down these the megass falls direct into the furnaces until the hopper is sufficiently full to cause the megass in the carrier to pass over that in the hopper. The surplus megass can either be discharged at the carrier end or be stored between each furnace by opening intermediate doors under the control of the attendant. No firemen are required. An attendant simply regulates the flue dampers to give the necessary steam, and adjusts the intermediate doors, to prevent too much megass from accumulating at one place. He also sees, by means of the peep-holes in the hoppers, that each furnace is taking its proper amount of fuel.

The apparatus shown in Fig. 5 utilises the weight of the megass to regulate its own feed. The hopper is hinged at *e*, *f* being an opening in the cross carrier, *d* a damper or sluice, and *c* a balance-weight. The megass passes down the shoot *b* to the furnace until it is full, and then the weight of the megass,

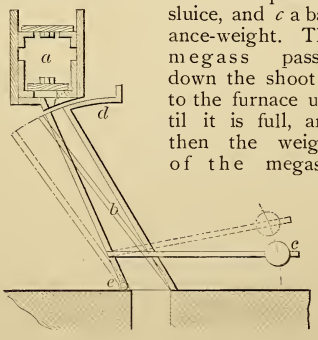


FIG. 5.

accumulating in the hopper, causes it to descend about the hinge into the position shown by the dotted lines, at the same time raising the balance-weight and sliding the sluice or plate

over the opening *f*, thus causing the megass to pass on to the next furnace.

In 1893 a furnace was tried by the author in which the fuel was passed through an open-ended retort, projecting vertically into the combustion-chamber. The flames of combustion heated this retort, and thereby heated, dried and distilled the gases out of the megass, ready for combustion so soon as they reached the combustion-chamber, the solid, partly-dried fuel falling upon a hearth surrounded by four pigeon-holed walls. It was found advantageous to block up the pigeon-holes until only 7 square feet of grate area were allowed for burning 7 cubic feet of megass. The ratio was thus 1 square foot of grate area per cubic foot of megass, whereas it had previously been 6 square feet of grate area per cubic foot of megass burnt per minute. In other words, with a boiler having 1300 square feet of heating surface, the furnace having one-third the usual grate area, the amount of steam obtained from double the quantity of megass was three times that derived from similar boilers with ordinary furnaces in the same battery, and this with a natural chimney-draught of 40 feet per second. The construction of the furnaces required only about half the number of bricks of ordinary furnaces.

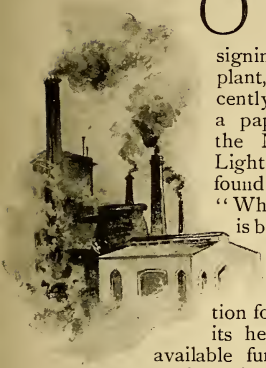
The loss of megass, and particularly of diffusion chips when charred and partly burnt, is considerable, on account of the unburnt carbon flecks. These are similar in appearance to the end of a charred match, and are carried through the furnace and up the chimney unburnt in such quantities that on a still morning the ground round a sugar factory becomes strewn with them to a depth of some inches. To prevent the waste from this cause, a centrifugal combustion-chamber, Fig. 3, has been successfully adopted for retaining the carbon flecks until they are distilled and completely consumed. The megass enters at *e* and falls to the fire-bars *b*. The flames are led into the combustion-chamber *d*, tangentially at *g*, so that the heavy unburnt particles are speedily separated from the light gases by centrifugal force—the heavy sparks and carbon flecks flying off to the circumference, and the light flames of combustion finding their way through the centre *g*, up the flue into the boiler *a*.

The same arrangement has been applied with success to the retort type of furnace, wherein the combustion or whirling chamber is arranged above the hearth, around which are fixed tangential tuyeres, supplied with air, preferably under pressure, from the chamber. The air enters the tuyeres and produces a whirling motion which causes the heavier unburnt particles of megass or chips to remain in the chamber, which is of large diameter, in virtue of their weight, whilst the lighter products of combustion pass up the deflector.

The economy of megass furnaces is still susceptible of great improvement, by the adjustment of the proportions in which the several constituents are consumed rather than by the introduction of new principles of construction or operation.

STEAM BOILERS: THEIR EQUIPMENT AND MANAGEMENT.

By Albert A. Cary.



ONE of the first considerations to be taken up in designing a new boiler plant, as detailed recently by the author in a paper presented to the National Electric Light Association, is found in the question, "What style of boiler is best adapted to our work?" and after this is answered the other question following closely at its heels is, "Are our available funds sufficient to equip this plant with the chosen form of boiler?" Unfortunately we find by no means a small percentage of prospective steam users asking these questions in the reversed order, and it is due largely to this fact that we find so many tank makers in the boiler business, so many coal companies flourishing and growing rich at the steam users' expense, so many boiler insurance companies springing up in every section of the country, to say nothing of the profits of the owner of the boiler, which unnecessarily go to keeping the boiler in repair and the coal pile replenished. All these troubles do not result from the doings of the "penny wise, pound foolish" man, but there is also a large percentage of the plants erected where ignorance has been the partner of the designer, and we find the outsider again reaping the profits which properly belong to the victim.

Where the load fluctuations on the engine are excessive, the boiler must be of such design that it will deliver a very large quantity of steam in a very short space of time, and this may be accomplished in several ways, viz.: first, by having a boiler with an abnormally large steam space; second, by having a boiler with a large water capacity, and a moderate-sized steam capacity; third, by having large hot water storage cylinders to supplement the quantity of water held in the boiler; fourth, by running the boiler at a steam pressure several times higher than that used at the engine and delivering the steam through a very large reducing valve, which reduces and delivers the steam from the high pressure to the pressure required at the engine.

Each one of these methods has its own advantages and disadvantages, and the first one is probably the worst arrangement that could be made. In fact, it may be regarded as impracticable. An extremely large steam space is neither desirable nor necessary; it increases the size of the boiler unduly, as well as increasing the heat radiating surface. Our second method of caring for the very sudden demand for steam is by providing a large water capacity. Under these conditions a fall in pressure is depended upon to supply the demand continuously.

With such an equipment, when the throttle is suddenly opened, admitting steam to the engine, the steam from the steam space of the boiler first rushes into the cylinder, and we will say, for example, that the boiler pressure drops from 100 to 80 pounds. Let us next assume that we are drawing our steam from a plant of boilers holding 100,000 pounds of water. The temperature of the water under 80 pounds pressure, we know, is 323.9 degrees Fahr., while its temperature under 100 pounds pressure is 337.8 degrees Fahr. By turning to our steam tables we find the total heat in one pound of water under the above conditions, as follows:—

One pound of water under 100

pounds of steam pressure contains 308.7 heat units.

One pound of water under 80 pounds of steam pressure contains 294.0 heat units.

Thus, when the pressure drops from 100 to 80 pounds, the total heat required in each pound of water is less by 14.7 heat units. Multiplying this by 100,000, we have 1,470,000 heat units available for the generation of steam. Divide this by 886.7 (the number of heat units necessary to evaporate one pound of water at 323.9 degrees Fahr. into steam), and we find that we have 1658 pounds of water evaporated during the time of the reduction of pressure from 100 pounds to 80 pounds. Now, if our engine uses 500 horse-power, and 60 pounds of steam are required per hour per horse-power (equal to one pound of steam per minute per horse-power, or 500 pounds of steam per minute for 500 horse-power), we divide 500 into 1658 ; we see then that from this lowering of temperature or pressure, we liberate sufficient heat to supply our engine with steam for about $3\frac{1}{3}$ minutes, even though all other sources of heat are withdrawn, but this is not the case ; the fire in the furnace will add its heat constantly at the same time, and thus we soon find an equilibrium established, and the boilers will finally be able to supply the engines steadily with the steam required.

Let us see how much of a boiler equipment we would need to cover the conditions we have just outlined. Let us suppose that we take horizontal tubular boilers, 66 inches diameter and 18 feet long, containing 46 four-inch tubes. One boiler of this kind (allowing one-third of the diameter vertically to measure the steam space) will hold about 14,000 pounds of water. Dividing this into the 100,000 pounds of water, we will find that it will require seven boilers, which, if rated by the regular builders' rating, would be sold at 668 horse-power. This is about one-third in excess of the rated engine horse-power, but, considering the excessive duty called for in such service, it can be considered as a well-balanced plant

The third method of providing for a great and very sudden demand for a large quantity of steam is accomplished, as has been stated, by providing one or more large hot water storage tanks which are used in connection with one or more regular boilers. The principle of working in this case is the accumulating of large quantities of heat in the water held in these tanks under pressure, to be called upon when needed, for steam-making purposes ; a very similar principle is followed in storing electricity in storage batteries, to be drawn upon at any instant when the current is needed. This is known as Halpin's system of thermal storage, and, in the case under consideration, its operation is almost identical to the second method just described, that is, it depends upon a fall in the steam pressure when the body of water gives up some of its heat which results in the formation of steam at a lower pressure. In this system, of course, a fewer number of boilers are used, but the quantity of water handled by these boilers is proportionally greater.

The arrangement of these thermal storage tanks in connection with the boilers is comparatively simple. The tanks are simply plain cylindrical boilers, but of course they must be capable of sustaining a pressure fully equal and generally much greater than the working boiler. The working boiler is run full of water, and is made to deliver a constant stream of hot water into the storage tanks, independent of the rate at which the steam is drawn from them, and for the best results this system should be run at at least 100 pounds pressure in excess of the pressure required at the engine.

We now come to the fourth method of supplying our sudden demand for steam, which was originated by the author. This is probably the most economical manner of solving this problem, first, as regards the original cost of the equipment, and secondly, as regards cost of operation. By this system the number of boilers required is reduced, the quantity of water needed is much less and this consequently lessens the

amount of fuel required, and the consumption of steam at the engine is also reduced. Of course we will need, for this system, boilers which can be safely operated under high pressure and let us here (for the sake of comparison with the example we have given under our second system) suppose that we have in our new plant two water tube boilers, each having a rating of 250 horse-power and running under 300 pounds pressure, supplying steam to our 500-H.P. rolling-mill reversing engine which is designed to work with 80 pounds pressure.

In the first place, we will be obliged to place reducing valves in our steam main, between the boiler and engine. This will probably require more than one valve as there is too great a range in pressure between 300 pounds and 80 pounds to be successfully handled by a single valve. The object of these reducing valves is to receive the steam from the boiler at a pressure higher than that required at the engine and by means of throttling, reduce this higher pressure to the 80 pounds required. The fall in pressure at the boiler side of the valves may run all the way from the 300 pounds down to almost 80 pounds, but the pressure on the reduced side of the valves will always remain a constant 80 pounds. Steam at any higher pressure than 80 pounds will only cause a waste of steam at the engine on account of the high terminal pressure at the end of the stroke. This, of course, refers to our reversing engine, while with an automatic cut-off engine, too high an initial pressure will cause, toward the end of the stroke, the wasteful negative pressure, which, on the indicator diagram, will be shown by the terminal loop. Returning to our rolling-mill engine, which is exhausted to the atmosphere, terminal pressure, of course, increases as the initial pressure is increased above 80 pounds. Thus it will be seen that reducing valves are a source of great economy in such practice. Those reducing valves must be very large, larger than required in ordinary practice.

As for the difference in expense in running boilers at a pressure of 300 pounds, instead of 100 pounds, it is hardly worth consideration. Practically speaking, a pound of coal will evaporate the same number of pounds of water into steam at any pressure. To show the truth of this statement, let us take a pound of steam at 100 pounds pressure, and again the same weight at 300 pounds pressure. The total heat in the first is 1185 heat units, while in the latter the total heat is but 1209.3 heat units, a difference of only 24.3 heat units, and when we consider that our coal delivers between 13,000 and 15,000 heat units when burned, from 60 to 75 per cent. of which are utilised by the boiler in making steam, no difficulty can be had in comprehending the statement that practically the same amount of water can be evaporated per pound of coal, irrespective of the pressure.

Now, in order to investigate the working possibilities of this arrangement, let us consider our plant somewhat in detail. Taking a well-known horizontal water tube, rated at 250 horse-power, we find that under ordinary working conditions, it contains about 20,000 pounds of water. Two of these, making a battery of 500 horse-power, will, therefore, contain 40,000 pounds of water. As has already been stated, our 500 H.P. rolling-mill engine is designed to be operated with 80 pounds pressure. The steam space and steam liberating surface in these boilers are designed to be of sufficient size and capacity to secure dry steam when the boilers are supplying the maximum demand. It must be remembered that all sudden lowering in the pressure of boilers is followed by an increased ebullition of the water, which has a tendency to project particles of water into the steam space, and if ample space is not provided to allow most of these particles time to drop back again into the water from which they have risen, before the out-rushing steam carries them away into the steam pipes, trouble is very apt to follow if this moisture is not entrapped or removed from the steam before it reaches the engine.

The exact steam liberating surface required in a boiler is pretty difficult to define, as experimenting in this direction has not determined this with any precision, but it is safe to say that when steam is taken from the surface of water at a speed greater than three feet per second, water is generally carried with it. A curious fact has been noted in this matter, and that is, after steam once begins to pick up water as it leaves its surface in a boiler, it will continue to do so for a considerable time, even though the speed of its exit is considerably less than the speed at which it first began to pick up the water. The advantages of reduced steam space have been already discussed under our first system. Next, let us consider the amount of water required here, and compare it with the second system. Here we have 40,000 pounds in our boiler, while there we had 100,000 pounds.

One pound of water under 300 pounds steam pressure contains 391.9 heat units. One pound of water under 80 pounds steam pressure contains 294 heat units. The difference is 97.9 heat units. We thus find that a drop in pressure in our boiler from 300 to 80 pounds will render available, from each pound of water contained in the boiler, 97.9 heat units; therefore, with 40,000 pounds of water we will have available 3,916,000 heat units to generate quickly the steam required. Dividing this by 886.7 (the number of heat units necessary to evaporate one pound of water into steam from the temperature of water under 80 pounds steam pressure), we find that we will have generated 4416 pounds of steam through this fall in pressure, and, as our engine requires 500 pounds of steam per minute, we find, by dividing, that we have a supply of steam which will supply our engines for 8.83 minutes, to say nothing of the steam generated directly by the fire during this interval.

Thus, we have almost three times as much reserve energy available as in the second system, while we have but two-fifths the amount of water. It is a well-known fact that water-tube boilers are very rapid steam makers, and in consequence of this, after dropping their pressure, as has just been stated, they will commence "picking up" immediately, and the nine minutes during which they are delivering steam from the available heat they have stored in the water under 300 pounds pressure are more than ample time for them to recover their maximum pressure again, and thus the desired result is accomplished.

To show where economy in operation occurs in this system, there are many points which may be considered. In the first place, there is a smaller number of boilers required, which need a smaller boiler house, thus economising room. Fewer boilers require fewer attendants. There is in this system needed but 40 per cent. of the water that is necessary in the second one, and that means that it will require but 40 per cent. of the fuel, when starting the boiler, to raise the water from the temperature of the feed to the temperature of the steam, and it must be remembered that the amount of iron work and masonry to be heated and maintained at a working temperature is far less in this system than in any other.

If we have a single-cylinder engine the lower pressure should be from 80 to 90 pounds, while with a compound engine, expanding its steam through two cylinders, 120 pounds has generally been found good practice. Passing steam through the reducing valve secures a most desirable result, aside from the mere reduction in pressure; that is, it either dries or superheats the steam delivered to the engine. A moment's reflection will assure us of this fact. We know that the total heat contained in one pound of saturated steam under 300 pounds pressure is 1209.3 heat units, and as there is practically no external work done by the steam when passing through the reducing valve, this pound of steam, although reduced to a lower pressure, must contain the same number of heat units. Dry saturated steam at 90 pounds pressure we find contains only 1182.9 heat units; thus we have (1209.3—1182.9) 26.4

heat units in excess of what is needed for dry steam. As dry steam requires but 0.48 of a heat unit to raise one pound one degree, we find that our reducing valve will raise the temperature of the steam at 90 pounds pressure, 55 degrees Fahr. above its normal temperature, providing the steam entering the reducing valve is dry. Should it, however, contain any moisture, this superheating effort will go toward evaporating the entrained moisture into steam.

I have already described the operation of the high-pressure boilers working with their reducing valves, and now you will doubtless say, What saving can there be in fuel with this arrangement? In case our station has been working to its maximum limit and the load is suddenly diminished, the heavy fires carried, in order to supply steam enough for our crowded engines, will require some little time to burn down to the point needed to supply steam under our reduced conditions. Again, after operating the boilers to supply a light demand for steam and a heavy demand comes suddenly, how can our light fires be brought up quickly to the intensity needed to meet the new requirements? These apparent difficulties can easily be overcome by using a mechanical induced draft with a regulating device, which will vary the intensity of the draft to suit the requirements.

As every one knows, combustion in boiler practice is controlled by the amount of air passing through the grates. As the supply of air is diminished, the fire grows dull and finally, when it is shut off entirely, the fire smoulders and is soon extinguished. The regulated mechanical induced draft is arranged so as to control the air supply of the furnace, and it works between wide limits of variation in a very short interval. This device is simply constructed by placing a fan in the flue between the boilers and the chimney. This fan is driven by means of belting by a small steam engine working direct upon the driving shaft, or by an electric motor. The speed of each of these driving devices is regulated by means of an attachment which is moved as the steam pressure varies in the boiler, very similar to the well-known action of the automatic damper regulator. This mechanically induced draft is not a patented device and so is open to all for use.

There are many electric light plants in which this system can be used to great advantage without the addition of the economiser, which will materially reduce the cost of installation. In some of these plants, we find the extreme maximum load lasting but two or three hours each day, and it will be merely during these times that the excessive temperature of flue gases exists.

After all, the matter of introducing any appliances to the steam plant resolves itself down to a simple commercial problem. Taking the matter of first cost and cost of installation, to which must be added the cost of maintenance, we can easily figure the interest on the investment. Next, after carefully considering the appliance, and securing, by personal investigation, the true results of other experience, you can determine with close approximation the real saving that the appliance will make to the plant. Next, balance up and you will be able to determine whether it is advisable to invest or not.

VERTICAL VS. HORIZONTAL TURBINES.

By Samuel Webber.

IN a consideration of the subject of vertical and horizontal turbines it may be interesting to refer, for a moment, to the origin and primary functions of the original vertical shaft wheel, which was used many centuries ago for the purpose of grinding the various grains which form the principal food of man.

This object was, undoubtedly, first attained by simple pounding with a mallet or pestle of stone, but it was probably soon discovered that a finer flour was secured by the rotation of one flat stone on another in a horizontal direction, and the old hand-mill, mentioned in the Scriptures, and still in use among primitive peoples, was evolved.

As man began to utilise the forces of Nature to aid his muscles, he found that he could readily apply the force of falling water to paddles set on a vertical shaft, which would give the necessary rotary motion to the millstones in the proper direction, without intermediate transmitting machinery, and from this early "flutter wheel" first the "tub wheel" and then the turbine were evolved.

There are certain purposes, like the uses for which it was originally devised, and certain circumstances, such as a very low fall of water, for which the original vertical shaft wheel is well adapted and, in the latter instance, indispensable; but when the waterfall is high, and the line of rotary motion, as in the great bulk of machinery, is vertical instead of horizontal, it becomes of advantage to mount the first motor or turbine on a horizontal shaft, and dispense with the bevel gears which are usually employed to change the direction of the motion.

The first notice I can find of the use of a horizontal shaft for a wheel in which the water is wholly confined and issues through apertures is in "Glynn on Water Power" (John Weale, 1853), in which Mr. Glynn speaks of its application to a pair of Archimedian scroll wheels, by Professor Redtenbacher, of Carlsruhe, Germany. The next is the one noted in CASSIER'S MAGAZINE of November, 1895, of the application, by Mr. Geyelin, of Philadelphia, of water to a pair of turbines, in 1854, in Mexico, under a head of 160 feet. Under this fall it is not probable that draft tubes were used, but about 1860 or 1861 the late John C. Hoadley put in a Parker scroll wheel, with rectangular wooden draft tubes, for the print works at Manchester, N. H., U. S. A., of which the writer was the manager.

The power from this wheel was transmitted by a belt directly to the main cylinder, or bowl, of a twelve-colour printing machine, and the result was so satisfactory that the writer devised a small inward-flow iron turbine, discharging through a quarter-turn into an iron draft-tube, and in the following year put in six of them. His attention to this matter was diverted by other business, and he thought no more of the matter until 1876, when Mr. A. M. Swain put in a pair of 24-inch turbines on a horizontal shaft, under 65 feet head, for the Lake George Manufacturing Company, at Ticonderoga, N. Y.

In 1879, the writer tested, at Holyoke, a pair of horizontal shaft wheels, built by Gates Curtis, of Ogdensburg, N. Y., and in 1880 he designed a plan for three wheels on one shaft, for the P. C. Cheney Paper Company, of Manchester, N. H. These wheels were made by Messrs. T. H. Risdon

& Co., of Mt. Holly, N. J., and worked to entire satisfaction under 39 feet head, of which 13 feet was above the wheels and 26 feet in the draft-tube.

It was the invention of the draft-tube by Amasa and Zebulon Parker, in 1840, which made horizontal shaft wheels possible, and after the success of the wheels above mentioned the system was adopted by all the prominent wheel builders, and is now fast superseding the vertical shaft, except in the cases above noted, where the fall is too low to use a horizontal shaft and keep the belts and pulleys above high water, or where the horizontal rotation of the machinery is desirable, as in an old-fashioned grist mill. With the modern system of roller milling, it is no longer needed for the production of flour.

The term draft tube may not be familiar to all, and a word of explanation may therefore be advisable. The Messrs. Parker, above mentioned, of Licking, O., discovered in 1840 that it was not necessary to set a "reaction wheel," as a turbine was then called, at the bottom of the fall, but that an equal result might be attained from them if they were set in an air tight chamber, not farther from the tail water than the ordinary limit of suction of a pump. This is theoretically about 34 feet, but is not practically so, as under any ordinary circumstances, a perfect vacuum is unattainable. The writer has had great difficulty in persuading well informed people, that the law of suction, as it may be termed, could be thus reversed, and the whole weight of the water in a tube, not over 30 feet in length, be made to bear on a turbine, set at any point in this tube. In the case above referred to, of the 26-foot draft tubes, at Manchester, Messrs. Risdon & Co. were skeptical, but the writer took the responsibility, instructing the boilermakers who made the tubes, "to think they were making a steam boiler." From 18 to 20 feet long is usually sufficient, and clears all the pulleys and belts from tail water. It should not be forgotten, however, to put in a blow pipe and valve, just below the wheel, to expel the air freely when the water is let on, but when running, this should be closed and the tube should be air tight.

All improvements work their way slowly at first. It took a long time to convince the old-fashioned millwrights that there could be anything better than the old breast wheel. It took a long time, also, to convince the owners of the great American cotton mills at Lowell, Manchester and Holyoke that anything could be equal to the expensive Boyden-Fourneyon turbine, and, even now, a similar turbine has been introduced at Niagara Falls, with its enormous vertical shaft.

It has been a long struggle to persuade people that there was no more loss of power in changing the direction of the water from horizontal to vertical in a draft-tube than there was in turning it from a vertical to a horizontal in a Boyden wheel. With proper curves in air-tight tubes, there is no loss of power except from friction, and if the tubes are of proper size that is slight.

I can quote no higher authority on this subject than that of the late James B. Francis, who wrote:—"On theoretical grounds, I believed that, if properly constructed and applied, there could be no sensible loss of power by this arrangement, over placing the wheel on a vertical shaft below the surface of the water in the wheelpit, but I desired to test it practically. . . . The tests I made satisfied me that the loss of power, if any, was very small—too small to be measured with the apparatus I had, and the advantages of dispensing with a step and with gears for transmitting the power far exceed, in my opinion, any loss of power due to this arrangement."

The loss of power in transmission through bevel gears is a very uncertain quantity. It is commonly estimated at about 5 or 6 per cent., but if the gears are not in perfect alignment, well lubricated, and in proper mesh, it may be much more. The writer has found much more than that difference by resetting gears in a mill which were out of true and grinding badly. A recent test, by the writer, of a wheel guaran-

teed to give 50 horse-power, from tests by Mr. Francis, on a vertical shaft, gave 47 horse-power when tested on the jack-shaft after passing through a pair of gears, or a loss of 6 per cent., and the gears and shafting there were in perfect order.

The saving of steps is also worth considering. The writer has seen at a certain mill, where the water in times of freshets was full of red sand, a bushel or two of worn-out, hard-pine steps thrown out behind the wheel house, which had accumulated in a short time. Now, it is an expensive job to pump out a wheel pit and replace a step, and this is entirely avoided by the use of horizontal shafts. Beside the loss of power in transmission through gears, the expense of attendance and lubrication is very considerable, while it is but a trifle to oil the bearings of a pair of wheels on a horizontal shaft twice a day, and by setting the wheels in pairs to thrust against each other, all end friction is avoided.

If, as in case of too low heads, vertical shafts are necessary, the gears should be planed to a centre, and the steps should be so arranged as to be always in water. A very good plan is to bore a hole through the step, vertically or axially in the centre, with a cross groove on top, and feed this through a pipe from the bottom with a stream of fresh water under pressure; this washes away any sand which may settle in the pit.

The case may be summed up in favour of the horizontal shaft, wherever the head is high enough to keep the belt pullies out of water, in the following words:

1. The saving of at least 5 per cent. power in gear friction.

2. The saving of the expense and annoyance of lubrication, with its constant distribution of black grease over everything in the neighbourhood.

3. The saving of all trouble from steps wearing out under water.

4. The convenience of having the wheel perfectly accessible at all times for examination or repairs, by means of a manhole in the case, although this may be done with any wheel where a draft tube is used.

5. The general comfort and convenience of a noiseless wheel, in a clean and well-lighted room, where wheel gates, belt pullies, and everything else are visible and readily accessible.

The horizontal shaft turbine has come to stay, as any of the great wheel-builders will tell anyone, from their present order books.

LOCOMOTIVES OF THE GREAT WESTERN RAILWAY, ENGLAND.

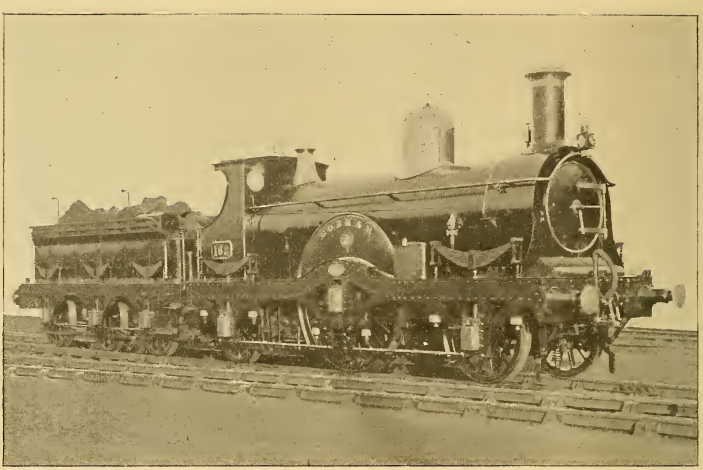
By C. R. King.

THE reproductions given herewith, from views of locomotives and rolling stock of the great Western Railway in England, are not without some pathos, for they serve to show how much one man, with too great authority, or of undue holding upon the estimation of others, can, at the commencement of an undertaking, conduct his collaborators by a road which will assuredly end in disaster, for though his views may be sound and his reasoning just, he cannot afford to stand alone, but must go with the stream of the majority.

It would be hazardous to assert that Brunel was wrong with his 7-foot gauge if we look thoughtfully at the great strides made in the enlargement of railway rolling stock even in the last de-

DISCARDED BROAD GAUGE LOCOMOTIVES AT THE SWINDON SHOPS.

ANOTHER VIEW OF THE ENGINES.



ONE OF THE CONVERTED ENGINES.

EARLY AND MODERN FORMS OF BROAD GAUGE CARS ON THE GREAT WESTERN RAILWAY.

cade,—when locomotive boilers have been amplified again and again, until their size has necessitated a very high centre of gravity, or they have been made elliptical in sections. One engineer builds two boilers, one on the top of the other, and yet another hangs two additional boilers from the sides of the main generator, in order not to adopt a boiler of very large diameter.

Besides boilers being uncomfortably crowded, the cylinders are hardly less so ; in fact, we appear to be cramping the future of the steam locomotive by the restriction imposed by high driving wheels upon a gauge of metals that Brunel thought too narrow.

However, he was wrong,—or at least we will go on considering he was until we have exhausted all mechanical ingenuity in keeping down the width of locomotive boilers, and Europeans will have abandoned forever the practice of inside cylinders from pure lack of space.

The year 1892 was death to Brunel's gauge. His successors gave way to the needs of the day, and the practice of the majority. Could he have seen the hundreds of locomotives, in perfect working order, the luxurious modern cars and freight trucks, representing a vast sum, all gathered together over acres of ground previous to breaking them up or converting them, the scene would, for him, have been a vast cemetery, representing the end of all for which he had toiled.

The converted stock, from its ample proportions, has given to the Great Western Railway some excellent types for its narrower gauge system. The illustration above represents a former standard express-locomotive designed by Sir Daniel Gooch. It has since been rebuilt with larger boiler and 18-inch cylinders. The following table of dimensions shows the proportions of the present standard express-engines which have replaced the big-wheel broad-gauge locomotives. For the first time the swivel truck, or bogie, has been introduced by the Great Western Company in these new engines :—

Cylinders—Diameter, 19 in.; stroke, 24 in.
Boiler—Barrel, 11 ft. 6 in. diameter.
Firebox—Outs, 6 ft. 4 in. × 4 ft.; ins. 5 ft. 8 in. × 3 ft. 4 in.; height, 6 ft. 2 in
Tubes—Number, 266; diameter, 1¾ in.; length, 11 ft. 0¾ in.
Heating surface—Tubes, 1434.27 sq. ft.; firebox, 127.06 sq. ft.; total, 1561.33 sq. ft.
Area of fire-grate—20.8 sq. ft.
Wheels—Bogie, 4 ft. 10 in.; driving, 7 ft. 8 in.; trailing, 4 ft. 6 in.
Water capacity of tender—3000 gallons.
Working pressure—160 lbs.
Total weight of engine and tender—81 tons, 10 cwt.

In this type of engine the elevated firebox-shell has been reintroduced as it existed in the old ones of the broad-gauge style ; previous to the creation of the new machines the sheathing of the boiler barrel, smoke-box and firebox shell was flush from end to end.

EARLY AMERICAN SAW-MILLS.

By Joel Sharp.

AN attempt to favour the readers of CASSIER'S MAGAZINE with an accurate history of the development of saw-mills in the United States, even to the exclusion of many details which would be of interest to a large number of them, is necessarily attended with considerable difficulty, by reason of there being so much unrecorded data, which must be gathered from the memory of those still living who are most familiar with such history.

Even the encyclopedias fail to give the most important steps in the development of the machinery used, and the application of the motive power. The *Britannica* speaks of several mills "along the Atlantic coast of North America about 1634, a description of one being that of all. In these mills

the saw was attached by a long pitman from the water wheel shaft to a ponderous saw-gate, running in wooden slides upon two heavy posts, crossed above by a beam connecting the two sides of the mill-frame. The mill carriage, on which the log lay, was pushed toward the saw by a rack and pinion, moved by a feed wheel. The daily capacity of these mills was from 500 to 1500 superficial feet."

This brief extract will, perhaps, give a fair idea of the crudeness and very modest capacity of the first mills of America, and history does not record any very marked fundamental improvement until the present century. If we give here, a brief record of the evolution of the saw-mill in Northeastern Ohio, where grew the majestic poplar, oak and other typical forest saw-mill timber, as it was pushed forward to its more modern state of perfection by the Sharps, who settled there in the early part of the century, we will perhaps have "told the story," so to speak, of the development of this industry, because theirs was pioneer work and their successive improvements were always in the lead.

Joel Sharp, Sr., the father of the Sharps referred to, emigrated to Salem, O., from New Jersey in the year 1806. He was a carpenter by trade. His eldest son Thomas, born in 1808, is the real hero of our story, because the evolution of the saw-mill and its necessary accompaniment, the introduction of the high speed engine, were both the results of his genius, courage and energy.

The "sash" saw-mill was generally popular until about the year 1833. They were generally water power mills, located in the heavy timber, frequently on small streams which were abundant in the country at that time. It is not uncommon to find the marks of those mills now, on streams nearly extinct, or entirely so, at the dry season of the year. The mills were necessarily limited in speed (say 60 to 100 strokes per minute) by reason of their ponderous saw-gate, which was necessarily twice the width of a 4-foot log, with a capacity not exceeding 1500 feet in ten hours, with most favourable timbers. We refer to those mills as the ones then in practice for country custom sawing, not to large lumbering establishments where rafting facilities were available.

The first really successful mulay saw-mill in northeastern Ohio was built by Thomas Sharp for Leonard Case, Sr., father of the founder of the Case School of Applied Science at Cleveland, O. This mill was erected five miles west of Cleveland in 1833. Its power was a 10"x36" engine of the style of those days, speeded 60 revolutions per minute with a 10-foot driving pulley and 12-inch belt, to a 2-foot driven pulley on the saw shaft, thus speeding the saw to 300 strokes per minute. This style of steam saw-mill was the one in general use until the late forties, except that shorter strokes and higher rotative speed engines were soon adopted, giving the saw 2½ to 3 strokes to one revolution of the engine, instead of five to one as before.

The Case mill above referred to was built under difficulties for the want of proper machine shop facilities. As a sample, the mulays were of wood, except the slides, which were furnished in the rough and had to be trued up at the mill by peaning, and dressed with file and grind stone. Iron planers were unknown in the country then. The first feed was a rag wheel of the old ratchet type that fed with each stroke of the saw. This proved unsatisfactory at a speed of 300 per minute, and a continuous feed by means of cone pulleys, belt and cog gear was substituted. This increased the capacity of the mill, say from 3000 to 4000 feet and sometimes, with favourable logs, to 5000 feet per ten hours.

Mr. Sharp operated this mill until the year 1842, when it was destroyed by fire. Then he returned to Salem and started a small machine shop, where he began building belted mulay saw-mills, gradually increasing the rotative speed of the engine until 1845, when he conceived the idea of a direct action mulay mill; viz., the engine and saw crank attached to the same shaft. The first of these mills ever built was turned out by

Mr. Sharp for a company in Mahoning County, O. They were a success from the start. They fully equalled the belted mills in capacity, and cost much less.

Thousands of them were erected in western Pennsylvania, Ohio, southern Michigan, Indiana, Illinois, Missouri, Iowa and Kansas, and a few south of the Ohio river. The engines were of the ordinary unbalanced slide valve type, with a valve at each end of the cylinder, light reciprocating parts, and very liberal port capacity, with a view to the largest possible freedom of exhaust, which, of course, involved large induction capacity so far as the slide valves were concerned. But the importance of the latter was lost sight of in steam pipe capacity, the relative proportions being, say, for a 6½″x16″ engine, a 4-inch exhaust pipe and 2-inch steam pipe or less.

We are indebted to the steam engine indicator for first calling our attention to this error in steam pipe capacity in the early seventies. However, even with the cramped steam pipe capacity the limit of speed was not with the engine, but with the saw and its connections. As to steam economy, the Case mill, with its 10″x36″ engine, required for fuel all the slabs and an equivalent amount of cord wood besides, while the direct-action mills became so perfected that the sawdust and chips furnished ample fuel where proper facilities were provided for burning the sawdust.

These mills, with reasonable skill, were good for from 7000 to 8000 feet per day, and were finally built by numerous other makers. Their complete success finally suggested the direct action circular saw-mill, and in 1856 Sharp, Davis & Bonsall (founders of the Buckeye Engine Company) built the first one of this kind for a large land owner in Iowa, who wanted a portable saw-mill to cut lumber to improve his farm. We remember that the gentleman came to Salem with his money in a belt under his clothes (bank checks were not as common then as now), and staid with us until we built and shipped his mill.

The foundation for this engine was on oak timbers, about 10″x20″, keyed at each end to solid oak stumps, about 2 feet in diameter and 15 feet apart. The mill was set properly on this and started without a shelter of any description. The engine was a 6″x14″ and drove a 54-inch saw. The capacity was from 600 to 800 feet of oak boards per hour when properly handled. This was doubtless the first direct-action circular saw-mill in the United States, if not in the world. The success of this mill encouraged the building of others of the same type, and in a few years they substantially superseded the direct mulay.

The engines for these mills that were furnished by the Sharps and their co-partners, were from 6″ to 8″ bore and 14″ stroke, and they, as well as the engines for direct mulay mills, were operated without a governor. The sawyer had control of a gate valve in the steam pipe by means of a lever, or a cord over pulleys, and ran the engine at any speed desired, generally at the rate of 400 or 500 revolutions per minute. For their duty the engines would stand up to this speed very well, as it was only for a few seconds at a time, or while a cut was being made; then the gate valve was partially closed and the speed reduced while the log carriage was backed, and the log set for the next cut. The practice called for a very light fly-wheel in order to stop and start quickly. The reciprocating parts of the engine were all made as light as possible, consistent with requisite strength. Disc cranks were always used, and balanced with the shaft on parallels. Experience with these engines demonstrated that, when doing hard work, they would run quietly at a very high rotative speed,—more so than at a slow speed. When the sawyer would start into the cut with a slow or moderate speed, the engine would pound, but as the speed increased the pounding would disappear almost entirely.

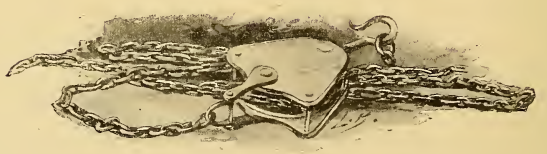
A test trial of direct mills was made by Sharp, Davis & Bonsall in the spring of 1857 as follows:—The mill proper was one of their regular direct mulay mills, with one boiler, 40 inches

in diameter, 16 feet long, with two 14-inch flues; engine, 6½"x17". On the opposite side of the boiler they set up, temporarily, one of their direct circular mills, with 6"x14" engine and 54" saw; both engines took steam from this boiler. With the mulay saw they cut in nine hours, from twenty-three poplar logs, 12,229 feet, all inch boards, except 1100 feet of 2-inch planks; and with the circular mill, in nine hours and four minutes, they cut from forty-two poplar logs 14,948 feet, all inch boards; in all, 27,177 feet. The fuel was 2½ cords of dry slabs.

There was nothing remarkable in this, excepting the amount of work done with those small engines. The firing was very brisk, and possibly half the heat generated went up the chimney. With a proper amount of modern boiler capacity, at least one-third less fuel would have done the work. The test was made to satisfy a competitive builder. Many of our direct circular mills were built with 8"x14" engines, and 60 to 66-inch saws. Sometimes a 30-inch top saw was added. With good-sized timber and proper handling, these mills had a capacity of 2000 feet per hour from our soft timbers.

During late years, since the remaining timber is very generally in small patches, the portable belted circular mill is doing country sawing, the power for it being furnished by agricultural engines of various types, the mills being moved from one timber lot to another, as desired by owners. These mills are necessarily of small capacity, say, with the present average of the timber, 1500 to 2000 superficial feet per ten hours.

In conclusion, we need only to add that the advent of the modern large gang mill with edgers, and steam feed, etc., in the great pine forests in the Northwest, where a large log is literally transformed into boards in one single trip, and where one mill turns out as high as 100,000 feet of lumber in a single day, has dispelled the necessity of any further advancement on this line, even though such were possible. Figuratively speaking, forests have already hoisted the white flag, and are crying "Hold! Enough!!"



FOUNDRY CRANES.

By A. E. Outerbridge, Jr.

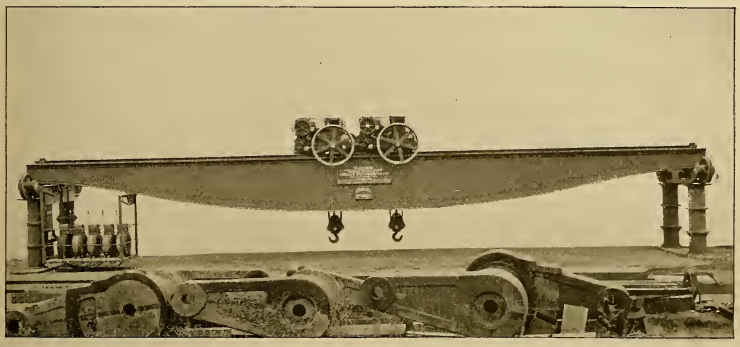
The matter given below was originally presented in the shape of an address, delivered at the inaugural meeting of the National Foundrymen's Association at Philadelphia last May. It was illustrated by numerous lantern slides, showing various kinds of jib and traveling cranes, installed and operating, and some of these have been here reproduced among others.

WE may readily believe that one of the earliest necessities of the primitive founder was some form of apparatus for handling his heavy materials, and crude appliances for this purpose are known to have existed from a very early period. It may, however, surprise those who have not investigated the subject historically to learn that records are extant showing that even the Egyptians possessed elaborately constructed derricks and other hoisting appliances.

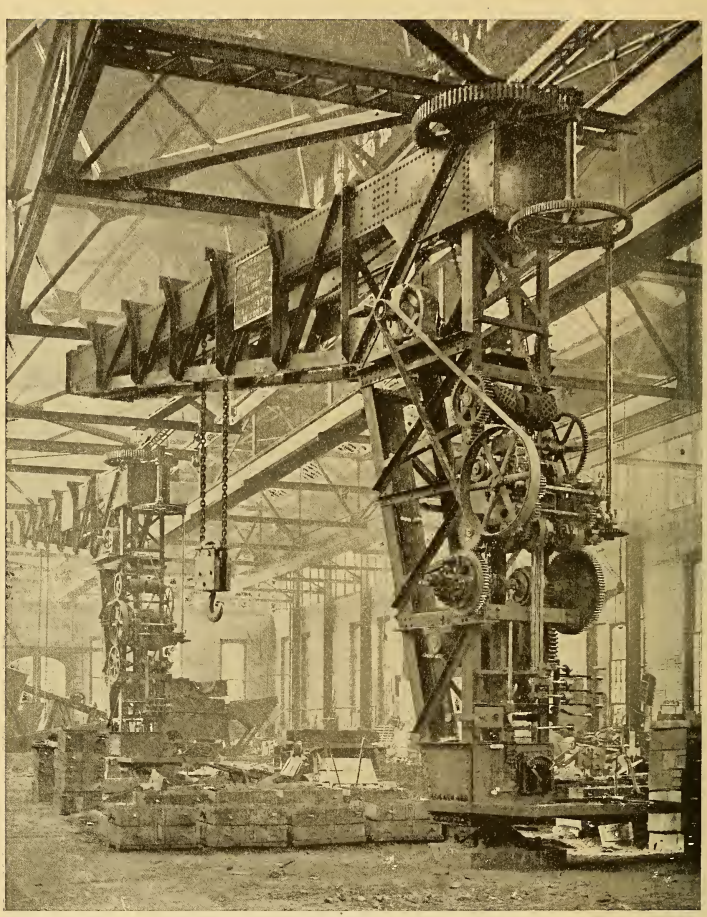
A gentleman who recently returned from an extended tour in that land of antiquity informed me that one of the most interesting places he visited while in Egypt was a large chamber, or vault, in the interior of one of the pyramids which contained the sarcophagus of the king who caused its construction.

The walls of this room were lined with large slabs of stone upon which were carved, in low relief, hundreds of figures, illustrating the method of constructing the pyramid, including the quarrying of the stone. Although my friend is not a mechanic, he said that the representations of derricks and other apparatus, with winches, ropes, etc., for hoisting and moving the large stones, resembled many of the appliances for similar uses which may be seen in parts of Europe even at this day.

These carvings are more than four thousand years old and are as sharply



A DOUBLE TROLLEY ELECTRIC TRAVELING CRANE. BUILT BY THE MORGAN ENGINEERING CO., ALLIANCE, OHIO, U. S. A.



A 10-TON ELECTRIC JIB-CRANE. BUILT BY MESSRS. WILLIAM SELLERS & CO., PHILADELPHIA, PA., U. S. A., FOR THE BALDWIN LOCOMOTIVE WORKS AT PHILADELPHIA.

Two hoisting speeds. Effective radius of jib, 30 feet. Operated by single constant speed motor. Arranged to lower by power or brake, as may be required.

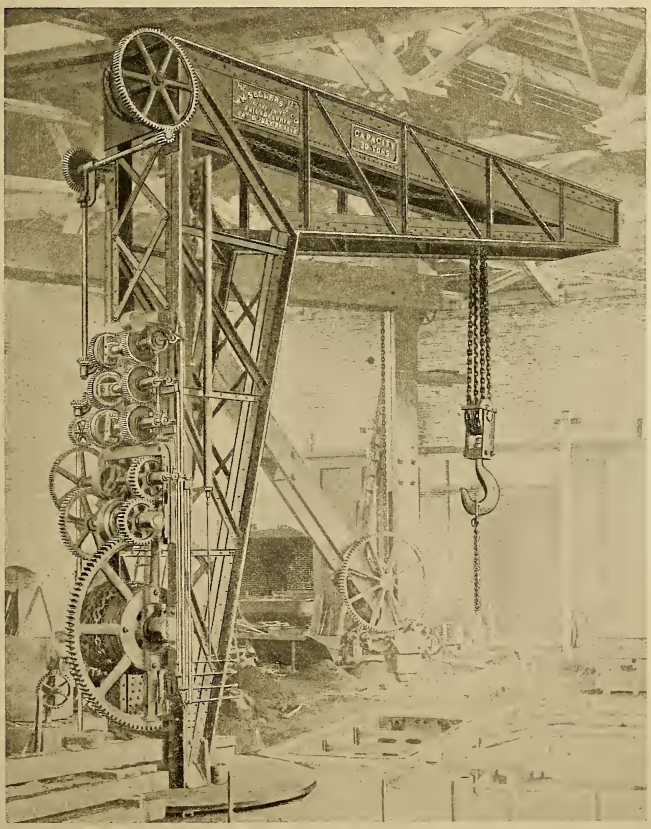
defined as when fresh from the graver's tool; even the original faint tracings of the artist could be detected in some instances. *

Coming down to a comparatively modern period, interest is attached to the illustration on page 223, being a photograph of an ancient drawing of a

* Mr. Ferguson, in his History of Architecture [vol. I, pp. 91-92], says —"No one can possibly examine the interior of the great pyramid (Cheops) without being struck with astonishment at the wonderful mechanical skill displayed in its construction. The immense blocks of granite brought from Syêné, a distance of 500 miles, are polished like glass, and so fitted that the joints can scarcely be detected. Nothing can be more wonderful than the extraordinary amount of knowledge displayed in the construction of the discharging chambers over the roof of the principal apartment, in the alignment of the sloping galleries, in the provision of ventilating shafts, and in all the wonderful contrivances of the structure. . . . . Nothing more perfect mechanically has ever been erected since that time."

crane devised by an English mechanic, Mr. Pinchbeck, which was examined by a committee of the Society of Arts of London, and to which the society's gold medal was awarded in the year 1767. Such a crane would excite attention as a novelty, even at this day. This picture will serve to establish the "state of the art" at that date and afford a starting point for a brief survey of the ground which has been covered in the past century, but more especially within the past decade.

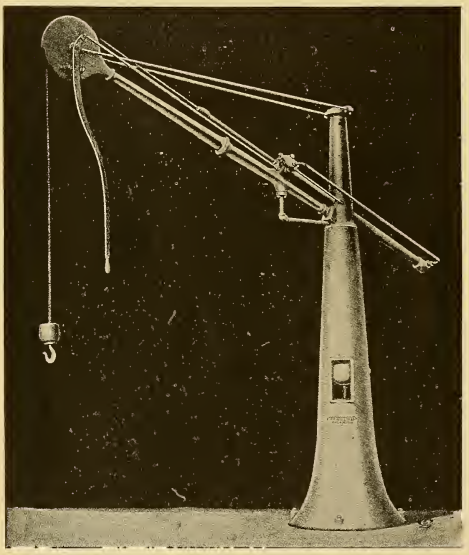
I find that while there are many references to cranes in text books on mechanics there is almost no literature devoted exclusively to this subject, and the ephemeral magazine articles, which appear from time to time, are mainly descriptions of new special apparatus. The impression might be gained from a perusal of these papers that the "swing" or "jib" crane is now almost obsolete,



A 30-TON SELLERS STEAM JIB CRANE IN THE FOUNDRY OF THE J. MORTON POOLE CO., WILMINGTON, DEL., U. S. A.

Height of post, 26 feet; effective radius of hook, 23 feet. All movements by power. Driven by independent 8 x 8 inch engines bolted to frame carrying machinery, receiving steam through upper pintle and discharging exhaust through step in foundation plate.

having been superseded by the modern "traveling crane." There are two erroneous impressions contained in such a conclusion; first, the jib crane is by no means obsolete, nor is it likely to become so in our day; second, the traveling crane is not so novel an appliance as many mechanics suppose. Overhead travelers were constructed and erected in at least one machine shop more than forty years ago and have been continuously and successfully operated ever since that time.



A SELLERS 1-TON HYDRAULIC PILLAR CRANE.

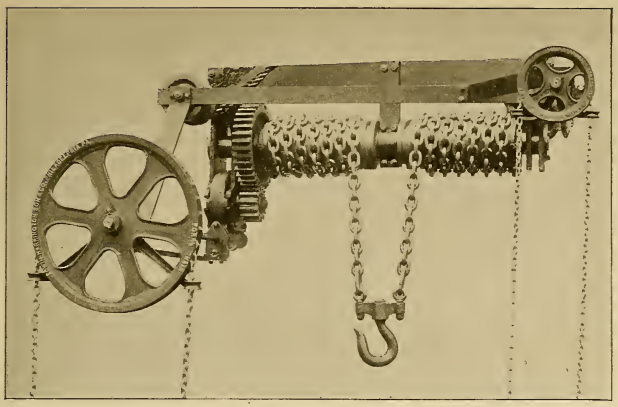
It is true that the constantly increasing magnitude of engineering constructions and the need of economy of time and labour in handling heavy materials used in such constructions has stimulated invention and has produced improvements in design and construction, which have enormously increased the efficiency of traveling cranes and have caused them, in many instances, to supersede the swing cranes which are more limited in their sphere of action. On the other hand, there are many situations which are not well adapted to the economical use of travelers, where "jib" or "swing" cranes are more advantageous and will, therefore, continue to be used; but, when we compare the modern improved high-speed jib crane,—having a light wrought-iron frame, safety clutches, electric motor, and other novel appliances,—with the cumbersome, old-fashioned, wooden prototype, we find that the jib crane, far from becoming obsolete, has been modernised and improved in quite as marked a manner as in the case of the traveling crane.

There are numerous subdivisions of both classes of cranes, such as pillar, column, derrick and locomotive cranes. Some have rotary motion around a mast or column; some have rectilinear motion, in which the load is moved in one or more directions in straight lines; they are, moreover, designated as hand, power, steam, pneumatic, hydraulic, and electric, according to the particular motive power.

There are certain fundamental principles which are applicable to all cranes. The first and most important consideration in a machine, designed to transport enormously heavy materials over the heads of workmen, is the factor of safety.

The second important consideration is that of speed, in which the ability to reach the load to be moved in the shortest possible time (whereby the preliminary operations of getting ready to lift are materially hastened) must be combined with a steady motion when hoisting the load—free from jar—and susceptible of the most delicate adjustment.

The third consideration—largely a consequence of the second—is that of economy of operation. This implies, in addition to quickness of movement,

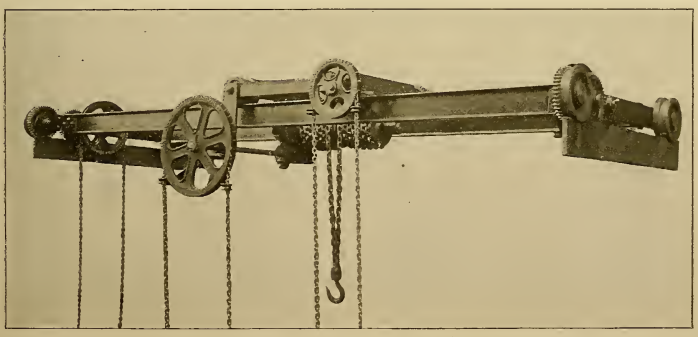


ENLARGED DETAIL OF THE CRANE BELOW.

the judicious location of all working parts within easy sight and reach, for facilitating oiling, tightening of nuts, etc., by the attendant when not operating the levers; ease with which parts may be removed for repairs, together with ample proportions of each piece in its proper relation to the whole, all tending to minimise the cost of maintenance.

The functions of the jib and of the traveling crane, while sometimes overlapping, are more often quite distinct. It may be said, in a general way, that in foundries where heavy castings are made—necessitating the handling of long flasks, large cores, and immense ladles of molten metal, the overhead traveling crane, occupying no floor space, and performing the work of a number of jib cranes more expeditiously, presents economic advantages of such importance that it has now come into almost universal use.

In establishments where miscellaneous work, of comparatively light weight, requiring frequent service by moulders, for short intervals of time, of a quick hoisting apparatus of moderate capacity,

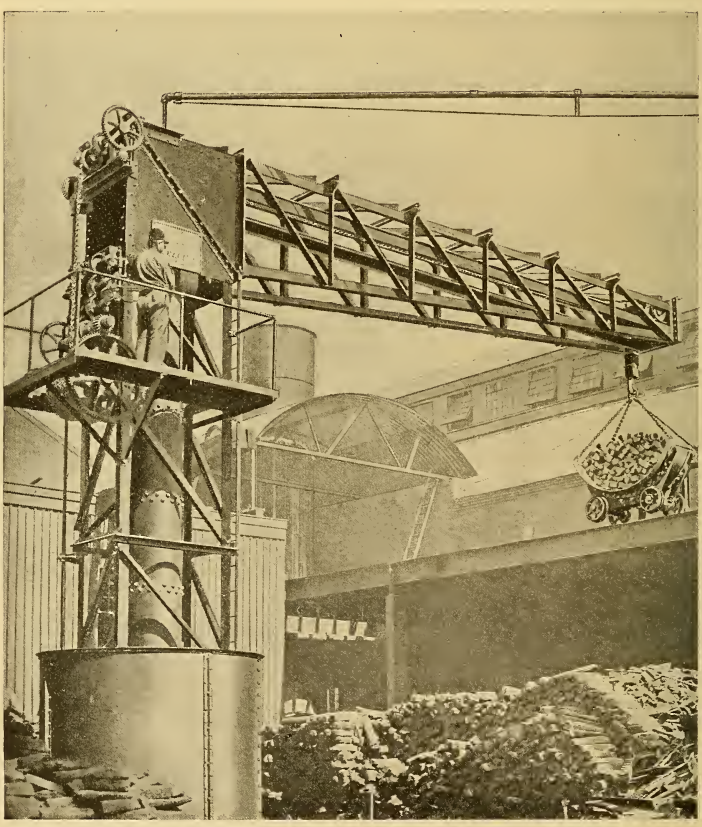


A SAFETY TRAVELING CRANE. MADE BY MESSRS. EDWIN HARRINGTON, SON & CO., PHILADELPHIA, PA., U. S. A.

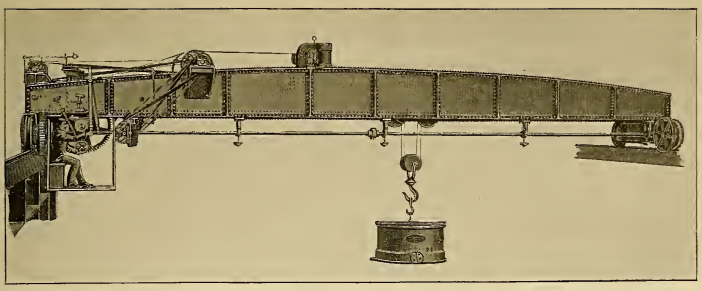
the modern jib crane, however, presents superior advantages; in not a few foundries a combination of jib and traveling cranes is found very economical.

There are local conditions which also exert influence in determining the relative value of jib or traveling cranes. A long narrow foundry, where moulds are situated at a distance from the cupolas, is better adapted to the use of traveling cranes than a foundry of different shape where the moulders' floors are, perhaps, laid out in circles and each moulder is more conveniently served by an independent jib crane, with its post in the centre of his floor.

I may cite—as an evidence of the comparative economy resulting from such appropriate arrangements—an instance coming under my own observation, where, in one car-wheel foundry, twenty wheels, 33 inches in diameter, make the usual day's work of a moulder, while ten moulds in another similar es-



A 5-TON STEAM PILLAR JIB-CRANE. BUILT BY MESSRS. WILLIAM SELLERS & CO.
Carried upon riveted steel pillar, bolted to foundation, driven by independent steam engine, and receiving steam from stationary boiler through top pintle bearing. Maximum height of hook, 25 feet. Effective radius of hook, 30 feet.



A 15-TON ELECTRIC TRAVELING CRANE. MADE BY MESSRS. THOMAS BROADBENT & SONS, HUDDERSFIELD, ENGLAND.

tablishment, without equal modern facilities, constitute the usual day's work, the only important difference between the two being in the superior facilities for handling flasks and wheels in the first named case.*

The old fashioned jib crane was an exceedingly clumsy construction of timbers, bolted together, braced with wrought iron rods and capped with iron castings. This composite structure was not only cumbersome in appearance and slow of motion, but it was subject to deterioration through shrinkage and decay, caused by heat, cold, and dampness.

Such structures are indeed obsolete to-day; but they have been replaced by jib cranes having a light framework of wrought iron, scientifically constructed, advantage having been taken of the great improvements and economies which have occurred in the manufacture of structural iron in recent years.

The tendency to follow in beaten tracks was evident even after wrought iron was substituted for wooden frames, but it was soon found that the rapid rotation as well as quick hoisting, required in modern cranes, demanded an entirely different structure, having much greater torsional stiffness.

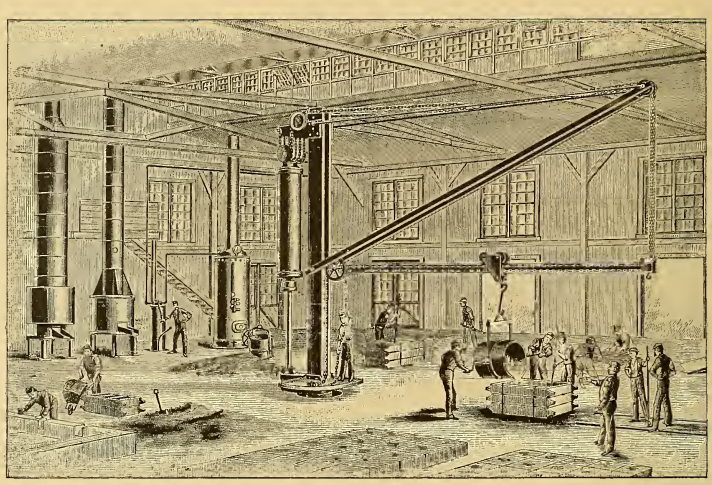
A basket framework of lattice girders, having both lightness and strength, was then substituted for "I" beams or channel bars, and, in the improved type, the trolley or carriage travels within the frame work of the jib, which is additionally strengthened by cross bracing across the top.

The post is latticed and cross braced on all four sides in the same manner, and wide plates are used to strongly unite the parts of the frame both at the top and bottom. The absence of a diagonal strut, such as is necessary in the old fashioned wooden jib cranes, permits the work to be moved much nearer to the axis of rotation than was formerly possible.

Jib cranes may be supported at the top, by bearings attached to the roof girders, by struts from the walls, or they may be made to embrace columns which support the floor of the building, or the column may be a pillar secured to a sufficient foundation requiring no support from roof or wall. In some forms of swing cranes the jib may be raised or lowered to increase or diminish the diameter of the circle.

In addition to the forms of cranes here described, there are a large variety of smaller hoists, operated by hand, as well as by pneumatic, steam, hydraulic and electric powers. Some of these are specially designed as attachments to

* A recent editorial in *London Engineering* [March 6th], entitled "Panaceas for Labour Strikes," instances the case of two ship yards side by side in one of which steam derricks are used for plating, and the price paid is 8 shillings per plate, whereas in the other yard the plates have to be lifted by manual labour, and the employer has to pay for the same size of plate 8s 6d. It is surprising that any firm should be without steam derricks, and there is little wonder that the men getting 8s. 6d. a plate earn less wage than those paid 8s.



HYDRAULIC CRANE. MADE BY MESSRS. CRAIG RIDGWAY & SON, COATESVILLE, PA., U. S. A.

machine tools, for lifting heavy work; others are used for raising and turning over flasks, in moulding; others are mounted on trucks and are especially designed for work in car wheel foundries. Indeed, the variety of special uses for small cranes is almost without limit, and in all, great improvements have been made both in quickness of movement and in lightness of construction.

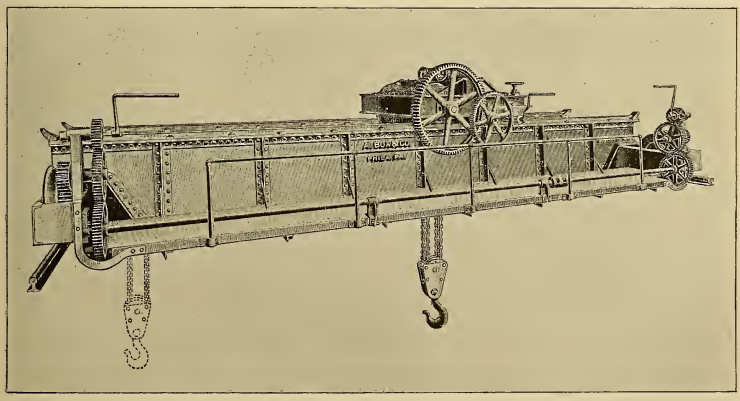
Foundrymen in America have, as a rule, been content with the simplest and cheapest forms of hoisting appliances which the character of their work would permit, but recently much more attention has been paid to improvement in the crane facilities of foundries and machine shops. This has been due, in part, to competition, which has compelled manufacturers to consider economy in every detail of their work and methods, and in part to the fact that crane builders have developed and improved foundry cranes, so that it is possible now to procure much more perfect machines of this character than could be obtained a few years ago. The electric motor has played a very important part in this development, since it affords a most convenient method of conveying power to a moving machine, like a crane.

The first marked improvements in swing cranes were in the direction of applying power—either steam or hydraulic—and, for some purposes, noticeably for Bessemer steel making, such cranes were carried to a high degree of convenience and efficiency. The swing crane, though well adapted to work where the weights to be lifted are confined to the area covered by the crane, —as in a pipe foundry or Bessemer steel pit—is not so convenient when it becomes necessary to handle product of varying size and shape, and to transfer such pieces rapidly from one end of a foundry, or shop, to another.

The time lost in adjusting chains and the inconvenience of reserving floor space for temporary resting places for such objects *in transitu* constitute objections to the swing crane under which many manufacturers are unwilling to continue to labour when it is no longer necessary. The traveling crane, covering, as it does, all the available space beneath it, if properly designed, does the work of many swing cranes.

Passing on to the study of traveling cranes we find that while overhead travelers have been used for many years, they were formerly crude devices, originally having wooden bridges requiring much splicing for long spans, besides trussing and bolting to add greater strength. They were usually operated by ropes or by independent engines.

These old traveling cranes were necessarily very slow in movement, and the improvements which have rapidly followed the substitution of iron girders for wooden trusses, mechanical —or, still more recently, electrical— power for hand movement, with addition of quick running gearing, increased lifting capacity, friction clutches, and other safety devices, etc., etc., have combined to produce practically a new machine and an invaluable aid to the founder, or other manufacturer.



A HAND POWER TRAVELING CRANE. MADE BY MESSRS. ALFRED BOX & CO., PHILADELPHIA, PA., U. S. A.

Various devices have, at times, been applied to conveying power to a traveling crane. Ropes, square shafts, grooved shafts, belts, compressed air, steam and hydraulic power have all been tried and are still, to some extent, used, but it was found that to operate heavy cranes at reasonably high speeds, the rope drive was entirely inadequate, and to transfer the necessary power by square shaft requires either a very large shaft or a very high rate of speed, and consequent large waste of power by friction. Then, again, the shaft revolves continuously, while the crane is operated at irregular intervals, often with long periods of rest, during which the shaft is absorbing an abnormally large share of power in the foundry or machine shop.

The electric motor has solved many of these problems, and it is now practicable to make traveling cranes which operate successfully and economically at speeds which would have been regarded as impossible by foundrymen ten years ago. Electricity is applied to cranes in various ways; thus, a motor may be used for each of the motions that it is desired to produce, the speed and duration of each movement being governed by controlling and stopping the speed of the motor. These are called "three motor" or "all electric" cranes, while others are operated by machinery situated at a fixed point on the bridge, and driven by a constant speed motor, the various movements being controlled and regu-

lated by a system of clutches and mechanical transmission devices.

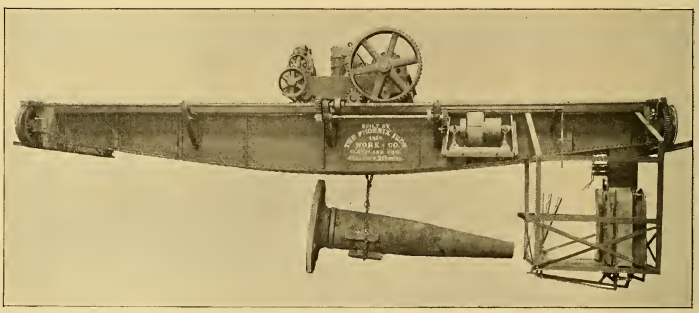
In the "all electric" type, the machinery, the motor, and the load are started from a condition of rest. In the latter case the motor and that portion of the machinery which is running while the crane is in service, act as a fly-wheel to assist in starting the load, with the result that there is less demand for current in cranes of this type at the moment of starting than in the former.

Before proceeding to describe in detail the various parts of traveling cranes, it may be well to pause for a moment to consider some of the essential qualifications of the perfect foundry crane. These considerations will apply equally well to all cranes.

I have already adverted to the necessity of absolute safety under all conceivable conditions. This implies that the load can never run down; it must always be pushed down by the hand of the attendant, so that if, in a moment of danger or excitement, he should suddenly desert his post, the load will remain automatically held until released by the operator.

The perfect crane must, moreover, move easily, stop and start gently, and must hoist vertically, no matter how many links of chain are paid out from the drum, so that the delicate operations of the foundry, such as raising, turning over and closing long flasks, etc., may be accomplished with absolute certainty. Every founder realises the importance of these conditions, not only in the specific operations named, but in others, —such as in the setting of large cores, drawing of patterns, etc.—they are even more imperative.

It would perhaps appear, at first sight, impracticable for one traveling crane to attend to the wants of a number of moulders in handling moulds and cores, and more particularly at "pouring-off hour," when ladles of molten iron must be handled without loss of time. Experience has shown that, under average conditions, one good modern traveling crane meets these severe requirements; it is certainly a tribute to its inherent capabilities that this should be the fact. Something, however, should be credited to the foundry foreman in this respect, for a clever man can modify the routine methods to suit the new conditions, so that these difficulties soon vanish and are forgotten, like many other ancient customs.



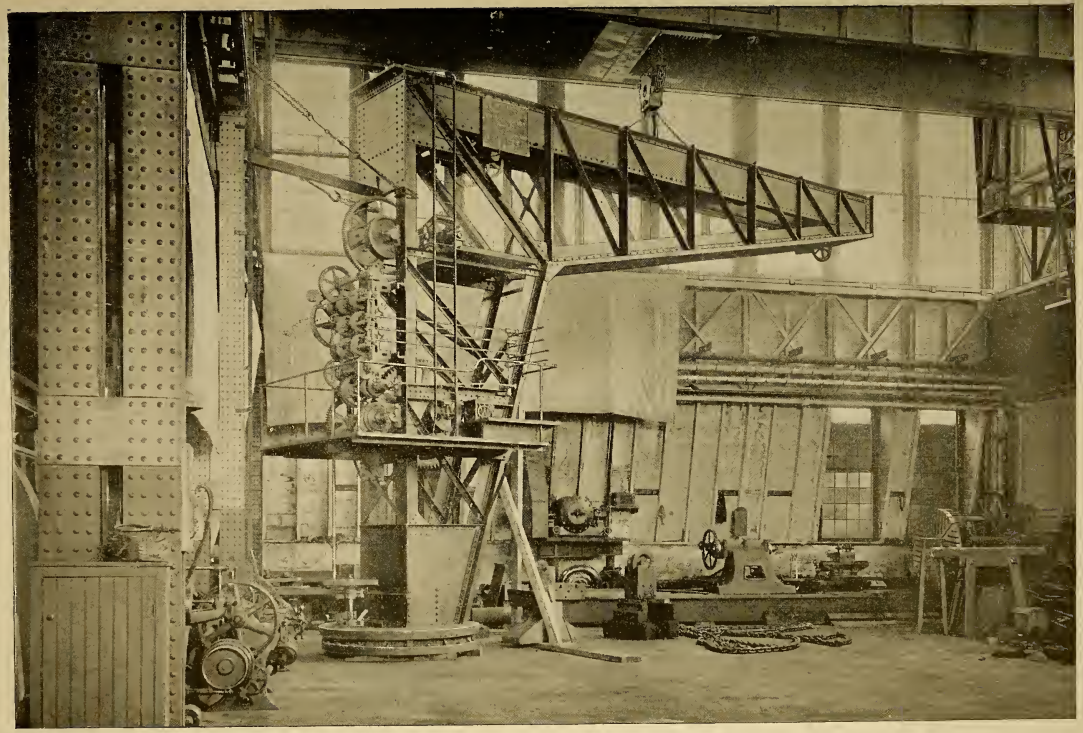
A 20-TON ELECTRIC TRAVELING CRANE. BUILT BY THE PHŒNIX IRON WORKS CO., CLEVELAND, OHIO, U. S. A.

The elevated railway traveling crane, as now constructed, consists of four essential parts:—

(1.) The elevated tracks.

(2.) The traveling bridge.

(3.) The trolley car, traversing the



A 20-TON ELECTRIC JIB CRANE. BUILT FOR THE CAMBRIA IRON CO., AT JOHNSTOWN, PA., BY WM. SELLERS & CO.

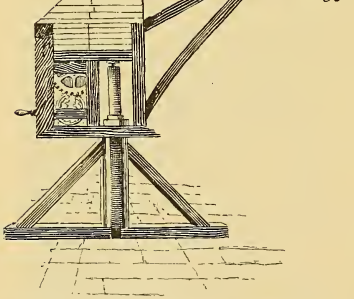
Effective radius of hook, 31 feet, 9 inches, and post, 28 feet high. Elevated platform for operator. Turning-gear at base of post. Driven by single electric motor.

bridge and carrying the hoisting mechanism.

(4.) The motor or driving mechanism.

The elevated tracks are supported by columns, or, in buildings specially constructed, they are sometimes built in and supported by the walls. These tracks run parallel and close to the walls from one end of the building to the other. The bridge is constructed of two parallel girders, extending from rail to rail, spanning in mid-air the breadth of the building. Four double-flanged wheels, usually steel-tired, with steel axles running in bearings, are bolted to projections on the girders.

The trolley car, also provided with double-flanged wheels, runs upon steel rails laid within or upon the bridge and bolted securely thereto. This car is provided with a grooved drum and double chain, wound thereon, carrying a forged swivel-hook, mounted securely in a hoisting block, the block being



AN OLD-TIME WOODEN JIB-CRANE, 1763.

furnished with sheaves through which the chain runs. In some large cranes the hook turns on ball bearings (more than 600 balls were used in one instance), and it is found that the friction is so reduced by these balls that one man can easily revolve a load of 50 tons, suspended from the hook. By properly arranging the grooves on the drum, and winding the double chain always toward the centre, a perfectly vertical lift of the load is assured.

I have carefully endeavoured in the foregoing descriptions of jib and traveling cranes to state only the broad general principles underlying this species of mechanism, avoiding allusion to any special features of different makers or of different designs of any one manufacturer, desiring to treat the subject in as comprehensive a manner as space will enable me to do.

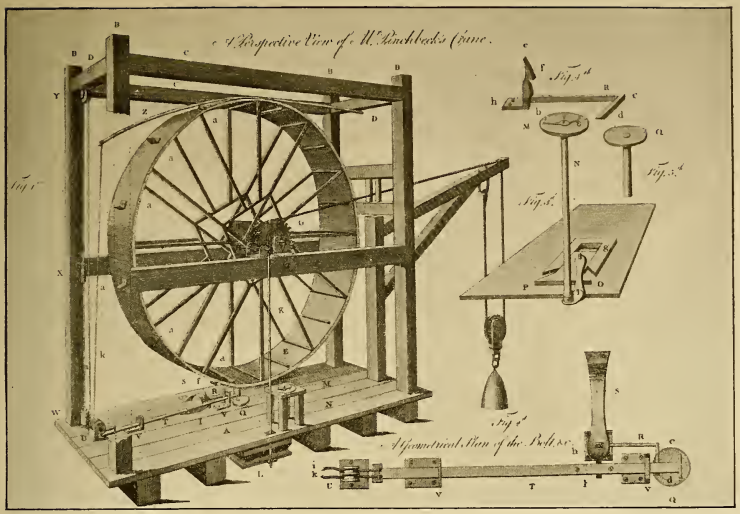
Through the kindness of Dr. Coleman Sellers, I am enabled to show a quaint and curious old wooden jib-crane illustrated in a rare work in four volumes in Dr. Sellers' library, entitled : "Dictionary of Arts and Sciences, published by the Society of Gentlemen, London, 1763." (See illustration on this page.) On the opposite page, too, is shown an early English "Walking Crane," so-called by reason of the method of operating.

I was fortunate enought to find among the rare and valuable old books which are hidden away in the Franklin Institute, a beautifully illustrated work, printed in London in 1782, entitled "Machines of the Society of Arts."

Through the courtesy of the secretary I am able to show the illustration of this English crane; I also have obtained a brief and imperfect description of it and a copy of the award, which is as follows:—

"This new invented crane of Mr. Pinchbeck was referred to the committee of mechanics who was of opinion that this method of preventing fatal accidents (which frequently happen in common walking cranes) is entirely new, ingenious, and very effectual for the purposes intended.

"A trial of the crane was made several times at Dices' Key, with an hogshead of potash, 6000 pounds weight, and it appeared to the committee that the invention will fully answer under all circumstances, and may be constructed at an easy expense; it was therefore recommended to the society, to give Mr. Pinchbeck the gold medal of the society for his ingeniously constructed



FROM AN OLD PRINT.

PINCHBECK'S WALKING CRANE, 1782.

and useful invention, to which the society agreed on June 3, 1767."

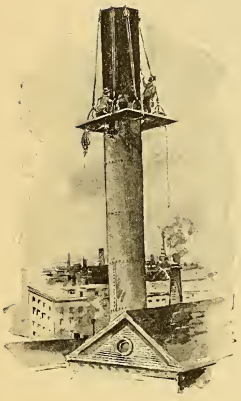
In the illustration, *E* is a great walking wheel in which men walk (evidently for hoisting the load). It is 6 feet 4 inches in diameter, and 1 foot 4 inches wide.

M is a dial-plate or regulator. The segment of this plate is divided into three equal parts, *1*, *2* and *3*, with a directing hand by which the motion of the walking wheel is regulated in the following manner: When pointed to No. 1, the aperture *g*, for discharging the wind out of the bellows, is dilated to its greatest extent to give vent to the wind; when set to No. 3, the aperture is contracted to its smallest dimension by which means the upper bellows retains the blast of wind.

Q is a lifting trundle, passing through the floor, extending so far below it as to be lifted up by the upper board of the receiving bellows when the walking wheel accidentally revolves with too great velocity. The trundle, latch, sliding bolt, and all other movements are at all times in a state of rest until the walking wheel is by some accident violently agitated, and when it so happens the expansion of the bellows will be so far extended as to lift up the trundle, latch, etc."

AMERICAN PRACTICE IN THE USE OF STEAM FOR PUMPING WATER.

By Wynkoop Kiersted.



THE success attending efforts to economise power by concentrating the power producing plant is too well illustrated by many practical examples to need defensive argument. The greatest success is obtained when the concentration of power embraces both the steam producing plant and the prime movers, the power being transmitted from a central station and applied in the desired locality.

In this brief article the author desires to discuss simply that source of waste of power exemplified in the operations of the inferior class of steam pumping engines so extensively used, both in manufacturing establishments and small water-works, and to compare the operation of that type of engine with that of other types.

With many industrial institutions the use of steam for pumping water is incidental; that is to say, it constitutes but a fractional part of the total use of steam and possesses but an incidental relation to the productions of the institution. Consequently, the installation of a plant for this portion of the work often receives little or no skilled consideration, and frequently a cheap and inferior grade of machinery is introduced without regard to the economy of operation.

Although in such a plant the consumption of fuel and steam may be enormous in proportion to the amount of work done, still the drain upon the resources of the establishment may not be felt, or may be tolerated, because of the comparatively insignificant amount of power consumed for this one purpose. But let the consumption of water become large, as in those operations requiring water in large amounts for cooling, brewing, refrigerating or other similar purposes, and the distribution of it be from several points more or less isolated; then the pumping expense becomes an important factor in the economical working of the establishment, and the low grade pumping engine develops to the fullest extent its abnormal appetite for steam.

It is essentially axiomatic, that unnecessary waste in any well regulated factory or similar institution is prohibitory. Tentative expedients which may have prevailed during the days of its infancy and during the progressive expansion of its business, cannot successfully continue when that business has assumed large proportions and when close competition demands a thorough organisation and an economical administration in every department.

However, attempts to reduce the cost of producing and utilising steam-power should be preceded by a development of the relations which one portion of the work in the establishment bears to another before instituting either partial or extensive changes in the character or general arrangement of machinery and its dependent parts. This relation is frequently so intimate as to materially affect the degree of economy which it is desirable to realise in the operation of the principal steam motors. For instance, when steam is

used extensively for heating purposes, it may be advisable to install non-condensing engines and to utilise exhaust steam for heating; or when an engine is installed and operated for a specific purpose, as electric lighting, it may be advisable to maintain as high a load factor as possible by transmitting power electrically from it for work of another character during intervals of a small load for lighting purposes.

Whatever general statements may be true of the proper conduct of private corporate business is also true of the administration of municipal affairs in all departments. The operation of a water-works plant as one of these departments can be conducted quite as successfully and economically as can such a plant under the management of a private corporation, provided there be a business-like management of the property under competent supervision, exempt from political influence and interference. That character of management will eventually prevail, as the accumulating results of experience favour municipal control and non-partisan management of water-works properties. Under such management the health of a community and the interests of the tax-payer are properly assumed to be in a position to receive the best protection.

The inclination of almost every community upon acquiring the management of a water-works by purchase or construction, is, at first, to reduce water rates or to establish a low annual charge for water. But such a course is not always in line with the best economy as water rates should be high enough to insure the proper maintenance of the works and the accumulation of a fund for betterments and extensions. It is better to install economical working machinery and to establish a business organization. Then a reduction of rates and other expenses will follow as a natural order of events at the proper time.

While a concentration of plant and power is, as a rule, in the line of economy, it is not a policy which can be unreservedly followed in detail. For that reason some cities, located upon undulating ground, supplying water by direct pressure from pumping engines, have the details of the pipe distribution system so constructed and the pumping machinery so subdivided into units that the supply of water reaches districts of the city on high ground independently of those on low ground. By that means the otherwise uneconomical working of a united distribution system and pumping plant is avoided. In such a system the pressure upon the entire system is regulated by the pressure requirements of the highest or most remote district.

Even an additional subdivision of the power plant may sometimes be advisable when the population is considerably scattered over an extended territory of varied and rugged topography. Here elevated districts, distant from the main pumping station, may frequently be most satisfactorily served by a high-service pumping plant, located in the district itself, taking water from the main distribution, probably through a small reservoir, and delivering it at an increased pressure throughout the elevated district. There may be several distinct services of this kind. The problem of satisfactorily and economically accomplishing such a subdivision of service is one of more or less complexity, confronting various cities.

In a few instances the aim is to render both domestic and fire service from a central pumping station. It can be accomplished by connecting each of the high or remote districts by an independent main with a pumping engine at the central station, designed expressly for service in its particular district. The obvious objection to this method is the heavy expense of laying independent district mains and of installing graded machinery, together with heavy interest and maintenance charges.

Another method is to install independent steam and pumping plants in each of the high-service districts, each plant to draw water from the district below in level or adjacent to it. Here the labour, fuel, and repair expenses would run high, because of the necessity to maintain and operate several independent pumping stations.

Again, the high service stations once established, the machinery may be operated by power transmitted electrically from an economically working generating plant, installed at the main pumping station or at the power station of some electric light and power company. Here the objection lies largely in the losses of energy resulting from the transmission and transformation of the electric current into usable power, and the expense attending the initial introduction of electric pumping machinery.

The author does not attempt here to compare the relative merits of the several methods suggested for distributing water by direct pressure over extended areas at variable elevations. It is rather a question for specific treatment. Besides, the data are too few to admit of generalisation. It is sufficient here to state that the question of operating high-service pumping machinery by power transmitted electrically, both for a constant and intermittent service, is before us for consideration on its merits. This is particularly true of an intermittent service, as when, in certain districts, the pressure needs increasing, for fire-service, above that which the machinery of the central pumping station is capable of furnishing. Thus, an electric pump, located in the hose-house of the elevated district and connected with an electric power plant at some central power station, would, under a fireman's supervision, be ready for instant service. It would obviate the necessity of carrying excessive and dangerous pressures at the central pumping stations upon occasions of fire.

A series of such plants, distributed judiciously as a part of the paraphernalia of the fire department throughout remote or high-level districts, would eliminate the necessity for fire engines, and would reduce, proportionately, the cost of maintaining the fire department. There are no insurmountable mechanical or engineering difficulties to defeat the success of such a project. The mechanical arrangement may be such as to insure a reasonably constant speed for the motor and pumps within the limits of their capacity, even under the condition of a fluctuating consumption of water.

Suburban towns, located on elevated ground, partaking of the water supply of an adjoining city at a pressure suitable only for domestic service, may avoid the expense of a fire engine equipment by installing in one of the hose houses of the fire department, properly located, a set of power pumps connected with a central electric power plant. They could thus possess an adequate fire service.

Small towns possessing both a waterworks and an electric light plant may, in certain cases, and with profit to themselves, utilise the power of the electric lighting plant to operate a power pump for pumping the public water supply instead of the inferior class of pumping machinery so often installed.

With these preliminary remarks the author would now attempt to illustrate the waste of steam-power resulting from the use of low-grade pumping machinery, and to discuss the feasibility of pumping by electrically transmitted power, by submitting estimates of cost of steam-power per unit of measure. To facilitate the making of these estimates, some data, bearing upon the question, are offered. These, it is believed, fairly represent certain results attending the operation of pumping engines under the prevailing conditions of practise:

Let D=Duty of pumping engine in foot-pounds per 1000 pounds of steam consumed by engine.

H=Head or total lift of pump.

V=Volume of water pumped per unit of time; for convenience, say, one hour.

W=Weight of unit of volume of water, say, 8.34 pounds per U.S. gallon.

S=Weight of steam consumed per unit of time, say, one hour.

$H.\ P.$=Pump horse-power. One $H.\ P.$ = 33,000 ft. lbs. of work per minute, or 1,980,000 ft. lbs. per hour.

C=Coal consumed per one $H.\ P.$ per unit of time, say, one hour.

Thus,

$$D=\frac{H\times V\times W\times 1000}{S}$$

$$H.\ P. = \frac{H \times V \times W}{1{,}980{,}000}$$

$$\frac{D}{H.\ P.} = \frac{1000 \times 1{,}980{,}000}{S}$$

or

$$\frac{S}{H.\ P.} = \frac{1000 \times 1{,}980{,}000}{D}$$

or $\frac{S}{H.\ P.} = \frac{1980}{\text{duty in million ft.lbs.}}$ = steam consumption per horse-power per hour.

From the last equation the following table is computed :—

Table.—Steam Consumption per H.-P. per Hour for Stated Duties in Million Foot-Pounds.

10	15	20	25	30	35	40	50	60	70	80	90	100	110	120	130	140	150
198	132	99	79.2	66	56.6	49.5	39.6	33	28.3	24.7	22.0	19.8	18.0	16.5	15.2	14.1	13.5

Coal Consumption per Horse-Power per Hour, at an Evaporation of 10 Pounds of Water per Pound of Coal, or when $C = \frac{S}{10\ H.P.}$, *for Stated Duties in Million Foot-Pounds.*

10	15	20	25	30	35	40	50	60	70	80	90	100	110	120	130	140	150
19.8	13.2	9.9	7.92	6.6	5.66	4.95	3.96	3.3	2.83	2.47	2.2	1.98	1.8	1.65	1.52	1.41	1.35

To illustrate the use of the table, suppose, upon test, that a pumping engine was found to consume 22 pounds of steam per pump horse-power per hour, as measured by the weight of water evaporated by the boiler during the test, and that the boiler evaporated 6 pounds of water per pound of coal. The duty, then, by the table would be 90 million foot-pounds per 1000 pounds of steam and 54 million foot-pounds per 100 pounds of coal consumed under the boiler, and the coal consumed per pump horse-power per hour would be about 3.6 pounds.

Upon a basis of ten pounds of water evaporated per pound of coal, the ordinary high-pressure pumping engine will give a duty of about 15 million foot-pounds; the non-condensing, compound, duplex, a duty of about 35 million foot-pounds; the ordinary condensing, compound duplex, a duty of 70 million foot-pounds, and the high-duty compound, or triple-expansion, duplex, a duty of about 110 to 125 million foot-pounds at a boiler pressure varying from 120 to 150 pounds. Engines of large capacity, of the triple-expansion marine type, will give a duty of 140 million foot-pounds or more at a boiler pressure not exceeding 140 pounds.

In the following comparative estimates, sections 1 to 30, inclusive, of the cost of a horse-power per year, it is assumed that the pumping plant has the capacity and power to deliver one million gallons per 24 hours against a head of 300 feet, equivalent to 53 horse-power of work; that the cost of fuel is $2 per ton of 2000 pounds; that the boiler evaporation is 6 pounds of water per pound of coal, and that the hours of work are 10 hours per day, plus 10 per cent. to cover the banking of fires, equivalent to 4015 hours per year. The estimates do not include labour, as that item of cost is assumed, without material error, it is believed, to be practically the same for each case.

HIGH-PRESSURE DUPLEX PUMPING ENGINE.

Sec. 1.—Working duty at 6 lbs. evaporation, 9 million foot-pounds; coal consumed, 22 lbs. per horse-power per hour, hence, cost of H.P. per year is $\frac{4015 \times 22 \times \$2}{2000}$ $88.33

Sec. 2.—Waste and supplies 0.70

Sec. 3.—Cost of pumping engine per H. P. is $21; engine consumes 132 pounds of steam per H. P. per hour; hence, one pump H. P. requires 3¾ boiler H. P., estimated, with heater, connections and all appliances, at $24 per H. P.=$90. Interest at 6 per cent., depreciation 4 per cent, repairs 4 per cent, insurance and taxes 1 per cent., total 15 per cent. on cost of engine and boiler plant ($111) amounts to 16.65

Cost per H. P. per year $105.68

COMPOUND NON-CONDENSING DUPLEX PUMPING ENGINE.

Sec. 4.—Working duty at 6 lbs. evaporation, 21 million foot-pounds; coal consumed, 9.5 pounds per horse-power per hour; hence, cost of H. P. is $\frac{4015 \times 9.5 \times \$2}{2000}$ equals $38.14

Sec. 5.—Oil and supplies ..... .80

Sec. 6.—Cost of pumping engine per H. P is $26; engine consumes 57 pounds of steam per H.P. per hour; hence, one pump horse-power requires 1¾ boiler H. P., estimated at $24 per pump H. P.=$42. Interest, depreciation, repairs, insurance and taxes, as per Sec 3, 15 per cent. on cost of plant ($26+$42=$68)= 10.20

Cost of pump H. P. per year $49.14

ORDINARY CONDENSING COMPOUND PUMPING ENGINES

Sec. 7.—Working duty at evaporation of 6 lbs., 42 million foot-pounds; coal consumed, 4¾ pounds per H. P. per hour; hence, cost of a H. P. per year is $\frac{4015 \times 4.75 \times \$2}{2000}$ = $19.06

Sec. 8.—Oil and waste 1 00

Sec. 9.—Cost of pumping engine per H. P. is $50; engine consumes 28.3 pounds of steam per H. P. per hour; hence, one pump H. P.= 0.8 boiler H. P., estimated at $24 per H. P. to be $19.20. Interest, depreciation, repairs, taxes and insurance at 15 per cent., as per Sec. 3, on cost of plant (69.20)= 10.38

Cost of pump H. P. per year $30.44

Let us now estimate upon a plant composed of a power pump of the same power and capacity as those stated for previous estimates, a motor, an electrical generator, a steam engine and furnishings. The pump operates occasionally for fire service at its maximum capacity; at other time it works but about 60 per cent. of its full load, and utilises in useful work only about 50 per cent. of the power in the steam cylinder. It is considered that motor, generator and engine carry about ¾-load on ordinary occasions, and that for the occasional fire service they may, with safety, be forced 25 to 30 per cent. beyond their rated capacities.

SIMPLE HIGH SPEED ENGINE.

Sec. 10.—Cost of engine, rated at 80 H. P., per pump H. P., is $28; one pump H. P. is estimated at 1½ boiler H. P. at $24 per H. P. = $36; motor of 60 H. P. at $17 per pump H. P.; generator, 75 H. P. at $21 per pump H. P.; or total for plant, $98 per pump H. P. Interest, depreciation, repairs, taxes and insurance 15 per cent., as per Sec. 3, on $98= $14.70

Sec. 11.—Power pump erected, $56 per pump H. P. Interest, depreciation, repairs, etc., as per Sec. 3, 15 per cent. on $56 is 8.40

Sec. 12.—Coal consumption, 11.4 pounds per pump H. P.; hence, $\frac{4015 \times 11.4 \times \$2}{2000}$ = ... 45.78

Sec. 13.—Oil and supplies for entire plant 2.00

Cost per pump H. P. per year $70.88

SIMPLE CORLISS ENGINE.

Sec. 14.—Cost of engine, as described in Sec. 10, $31; boilers at ratio of 1.4 to 1 at $24 per H.P., =$33.60; motor and generator, as per Sec. 10, $38; total, $102.60. Interest, depreciation, repairs, insurance and taxes, 15 per cent. on total cost ($102.60)= $15.39

Sec. 15.—Power pump, as per Sec. 11 ..... 8.40

Sec. 16.—Coal consumption at 80 lbs. boiler pressure, 10.6 pounds per pump H. P. per hour; hence, $\frac{4015 \times 10.6 \times \$2}{2000}$ = ... 42.56

Sec. 17.—Oil and supplies, as per Sec. 13 ..... 2.00

Cost of pump H. P. per year $68.35

COMPOUND HIGH SPEED ENGINE.

Sec. 18.—Cost of engine, of power as per Sec. 10, $29.19; boilers at ratio of 1¼ to 1 at $24 per H. P., $30.00; motor and generator, as per Sec. 10, $38; total, $97.19. Interest, depreciation, repairs, insurance and taxes, 15 per cent. on $97.19 ..... $14.58

Power pumping engine, as per Sec. 11 ..... 8.40

Sec. 19.—Coal consumption at 125 pounds boiler pressure, 8.15 pounds per pump H. P. per hour; hence, $\frac{4015 \times 8.15 \times \$2}{2000}$ = ... $32.72

Sec. 20.—Oil and supplies, as per Sec. 13 ..... 2 00

Cost per pump H. P. per year $57.70

CONDENSING COMPOUND HIGH SPEED ENGINE.

Sec. 21.—Cost of engine, rated 80 H.P. per pump H. P., $35; boiler at ratio of .9 to 1 at $24 per H. P.=$21.60; motor and generator, as per Sec. 10, $38; total, $80.60. Interest, depreciation, repairs, insurance, taxes, 15 per cent. of $80.60 = ... $12.09

Power pump, as per Sec. 11 ..... 8.40

Oil and supplies 2.25

Sec. 22.—Coal consumption, at 125 lbs. boiler pressure, 6.3 pounds per pump H. P.; hence, $\frac{4015 \times 6.3 \times \$2}{2000}$ = ... 25.30

Cost per pump H. P. per year $48.04

CONDENSING COMPOUND CORLISS ENGINE.

Sec. 23.—Cost of engine, 80 H. P., per pump H. H., $52.00; boilers at ratio 0.83 to 1 at $24.00= $19.92; motor and generator, as per Sec. 10, $38; total, $109.92. Interest, depreciation, repairs, insurance and taxes, 15 per cent. of $109.92 ..... $16.50

Power pump, as per Sec. 11 ..... 8.40

Oil and supplies 2.25

Sec. 24.—Coal consumption, at 125 lbs. boiler pressure, 5.5 pounds per pump H. P. per hour; hence, $\frac{4015 \times 5.5 \times \$2}{2000}$ = ... 22.00

Cost per H. P. per year $49.15

Upon the basis assumed, no economy will result, as might have been anticipated, in operating a small water-works by electricity, the plant having been erected exclusively for that purpose. Even an inferior grade of pumping engine would be found quite as economical for 10 hours work, as would the use of power transmitted electrically from a high-grade engine. Were it practicable to avoid carrying surplus capacity and power for the occasional fire service, and were the plant operated continuously at its most economical capacity, as might be the case when pumping into a reservoir, an efficiency of 65 per cent. instead of 50 per cent. might be realised.

In that event the proportions of the plant as estimated upon would not be changed, inasmuch as a 53 horse-power pump and a 80 horse-power engine represent about the proper relation of capacity for an efficiency of 65 per cent. at full load. But it is estimated that a saving of 55 per cent. of fuel will result for a given amount of water pumped per year, because the plant, at full load, need be operated but 2512

hours per year, allowing 15 per cent. for banking fires, and because of the saving of fuel resulting from an operation of machinery at constant full load instead of at fluctuating ¾ load. The following table admits of a comparison between the cost of a horse-power per year at 50 and 65 per cent. efficiency, including the saving resulting from reduced hours of work.

Sec. 25.—

Description Engine.	Efficiency— 50 per cent. Cost per H.P. per Year.	65 per cent. Cost per H.P. per Year.
Simple high speed	$70.88	$45.72
Simple Corliss	68 35	45.13
Compound high speed	57.70	39.80
Con. compound high speed.	48.04	32.78
Con. compound Corliss	49.15	37.20

However, when an electric light plant is already installed for lighting purposes, the engine and boiler at least may in most cases be used during the day to operate pumping machinery. Therefore, in that event, the estimates of the cost of a horse-power per year should exclude the interest on engine and boiler, but the pumping plant expense account should be charged with one-half the cost of repairs and depreciation. Hence:—

Simple High Speed Engine.

	Efficiency— 50 per cent.	65 per cent.
Sec. 26.—From the cost of a H.P. per year, Sections 10 to 13 (inclusive) and Sec. 25	$70.88	$45.72
Deduct 11 per cent. of engine and boiler at $60 per H.P	6.60	
Oil and supplies	1.00	
	7.60	7.60
Cost per pump H.P. per year.	63.28	38.12

Simple Corliss Engine.

Sec. 27.—From the cost of a H.P. per year, Sections 14 to 17 (inclusive) and Sec. 25	$68.35	$45.13
Deduct 11 per cent of cost of engine and boiler at $64.60 per H.P	7.11	
Oil and supplies	1.00	
	8.11	8 11
Cost of a pump H.P. per year	60.24	37.02

Compound High Speed Engine.

Sec. 28.—From the cost of a H.P. per year, as per Sections 18 to 20 (inclusive) and Section 25	$57.70	$39.80
Deduct 11 per cent. of cost of engine and boiler at $59.19 per H. P.	6.51	
Oil and supplies	1.00	
	7.51	7.51
Cost of pump H. P. per year	50.19	32.29

Condensing Compound High Speed Engine.

Sec. 29.—From cost of H. P. per year, as per Sections 21, 22 and 25	$48.04	$32.78
Deduct 11 per cent. of cost of engine and boiler at $56.60 per H.P.	6.13	
Oil and waste	1.00	
	7.13	7.13
Cost of pump H.P. per year.	40.91	26.65

Condensing Compound Corliss Engine.

Sec. 30.—From cost of H. P. per year, as per Sections 23, 24 and 25	49.15	37.20
Deduct 11 per cent. of cost of engine and boiler at $71.92 per H.P	7.91	
Oil and supplies	1.00	
	8.91	8.91
Cost of pump H. P. per year.	40.24	28.29

Other conditions than those embraced in the deductions of cost per horse-power at 50 and 65 per cent. efficiencies plus saving due to reduced hours of work may give a cost of a horse-power per year between those given in sections 26 to 30 inclusive. Under favourable conditions, a town possessing an electric light plant, equipped with an economical working engine may realise a saving by pumping water with electric power instead of with an inferior grade of steam pumping engine.

A manufactory having to pump water at several isolated points and having installed, as is usually the case, a large and economically working electric plant, can supply power electrically from this plant for pumping purposes at a cost per horse-power per year less than the work can be done by independent steam pumping plants erected at each of the several points.

Let us, for illustration, consider an establishment using 3 million gallons of water per day. The supply is elevated 100 feet by three independent pumping plants, each of one million gallons capacity. Assume the engines to be compound condensing, affording a working duty of 42 million-foot-pounds. Then:—

Sec. 31.—Cost of pumping engines, 3 plants, 53 combined H. P	$5,100
Boilers, 3 plants	1,900
	$7,000

$$\text{Cost per H.P.} = \frac{7000}{53} = \$132 \text{ approx.}$$

Sec. 32.—Interest, etc., as per Sec. 3, at 15 per cent. on the cost of 3 pumping plants at $132 per H. P.	19.80
Oil and supplies	3.00

Sec. 33.—Coal consumed at 4¾ lbs. per H. P. for 4015 = 9.53 tons at $2=	$19.06
Sec. 34.—Attendance on plant at $40 per month for each of three men per pump H.P.	27.17
Cost per pump H. P. per year.	$69.03

In comparing this cost of a horse-power for pumping with the cost of a horse-power resulting from the use of power transmitted electrically, the pumping expense account should be charged with but a fraction of the annual cost of interest, depreciation, repairs, etc., upon the engine and boiler plants. On the other hand, it should be credited with the value of the fuel saved by reason of an increased engine "load factor"—that is to say an increase in the ratio of the average load to the maximum load during a day's work. I have here assumed these items of cost and saving to offset each other. Moreover, various other economies may be practised which will, in all probability, enable the power pump to utilise 60 per cent. of the power furnished by the engine. Hence:—

Sec. 35.—From the cost of a horse-power as estimated, Secs. 14 to 17		$68.35
Deduct 15 per cent. of cost of engine and boiler.	9.69	
Deduct waste and supplies.	1.00	
Deduct for coal if an efficiency of 60 per cent. be allowed and engine works at ¾ load	7.00	
		17.69
		50.66
Add for the cost of attendance ⅓ the cost of Section 33		9.05
Cost per pump H. P. per year.		$59 71

Sec. 36.—For the other types of engines, as per Sections 28, 29, 30, the cost of a H. P. per year would be at 50 per cent. efficiency, respectively, $56.87, $47.60; and $46.41; at 60 per cent. efficiency, $51.41, $43.38 and $42.01, allowing in each instance $9.05 per H. P. for labour.

The extent to which the interest on the cost of buildings enclosing the several plants estimated upon, and on the cost of wiring between generator and motor, may modify the results, cannot be determined with sufficient accuracy to be of value in connection with the preceding estimates; but, certainly, there is no probability that any modification which it may be found necessary to make will result in a favourable showing for low-grade steam pumping engines. In fact, for small water-works and factory purposes either the duty of the pumping engines, as usually installed, must be increased by superior workmanship and design, or eventually they will be supplanted by power pumps operated by power transmitted from some economically working engine, particularly if for certain periods of the day surplus power can be utilised.

Passing now to high-duty pumping engines of large capacity of from 250 to 500 horse power, we find that a modern, vertical, triple-expansion engine will give a working duty, at 6 pounds evaporation, of about 80 million foot-pounds, and that the compound engine of the same type will give a working duty of about 80 per cent. of the above, or 64 million foot-pounds. For the usual service the former can be erected for $125 per pump horse-power, and the latter for $104 per pump horse-power, including boilers, foundations and furnishings.

Either of these engines, working 4015 hours per year, or upon the basis of former estimates, except that the price of coal is taken at $2.25 per ton of 2000 pounds, the additional 25 cents being intended to cover cost of delivery at either a high or low-service pumping station, will give a cost of about $31.50 per horse-power per year, exclusive of attendance, and $54 per year including attendance.

A compound or triple-expansion Corliss engine of from 250 to 500 horse-power, including power pump, boiler, generator and motor, but excluding pole line and attachments will cost scarcely less than from $150 to $155 per pump horse-power. Assuming an efficiency of 65 per cent., the plant will furnish a pump horse-power per year for $42, exclusive of attendance and interest, depreciation, repairs, etc., upon the cost of the pole line. It is not probable that the attendance necessary to operate the power plant for either a high or low-service pumping station will be less than two-thirds that estimated in previous paragraphs ($22.50). Therefore, adding to $42 two-thirds of $22.50 there results $57 as the cost of a horse-power delivered at the pump by a high-grade engine exclusive of interest, etc., on the cost of pole line and attachments.

Assuming the plants to be operated continuously, but the data otherwise remaining unaltered, the cost of a pump horse-power per year for a triple-expansion engine, including attendance, would be $97; for compound engine $99.60; and for the electrical transmission plant $96,80, exclusive of interest and maintenance charges upon the cost of the pole line and upon the extra cost of reserve machinery.

In a plant of the capacity of the one just estimated upon it is not probable that any central station will contain the surplus electric power necessary to operate a large power pumping plant. Butwhenever a new installation of boilers and engines becomes necessary in order to operate the power pumps, there is little probability that a power plant can be operated as economically as a high-grade pumping engine, even though the location of the power plant admits of a lower cost of fuel and attendance.

In determining the most economical arrangement of power for pumping purposes, and the grade of engine, it will be found that existing conditions may materially modify the unit cost of power as estimated. For instance, if the plant, Sections 21 and 22, operate every hour of the year, namely 8760, instead of 4015, as estimated, then the cost of a horse-power per year would be $79.68, while the cost per horse-power per year, Sections 23 and 24, upon the same basis, would be $77.08, the condensing compound Corliss engine, because of the more continuous service, becoming cheaper than the condensing compound high speed engine. It follows, therefore, that the continuity of service becomes a factor in determining the character of power it may be advisable to install; the more constant the service the greater the necessity for high-grade engines.

Other conditions, as the cost of fuel, labour, freight, etc., must also become factors in a final solution of the power problem. However, we may safely conclude that low-grade pumping engines will eventually be supplanted by those of a more economical type or by a power pump operated electrically from a plant established for work of another character under conditions favourable to such a combination. Many small towns and factories can, undoubtedly, be benefited by such a change.

High-grade pumping engines, handling a large volume of water, will scarcely be brought into competition with power pumps operated by electricity derived through the efforts of generators and steam engine. For the pumping of small quantities of water at high-service stations, or for an intermittent service, or for fire service in a high level or remote district, however, there is, doubtless, a future for the application of electricity.

WILLIAM SELLERS.

THE name of Sellers has become almost a by-word for excellence among engineers and machinery users not in the United States alone, but wherever machine tools are employed, for at the Vienna Exhibition in 1873, the recommendation for the award of the Grand Diploma of Honour to Wm. Sellers & Co., was "for pre-eminent achievements in the invention and construction of machine tools, many of which have been adopted as models by the constructors of tools in all countries."

The ancestors of William Sellers have had a long and memorable connection with science. From the organisation of the American Philosophical Society, some one of his family has always been a member of it, and William Sellers is now a member. His paternal great grandfather, John Sellers, then a mem-

ber of the Assembly of Pennsylvania, was appointed by this society, in connection with three other members, to observe the transit of Venus in 1769, and his maternal great grandfather, William Poole, came from England to observe the same transit and remained here.

Mr. Sellers was educated at a private school maintained by his relatives for the education of their children, acquired the machinist's trade with his uncle, and at the age of twenty-one took charge of the large machine shops of Bancroft, Nightingale & Co., manufacturers of steam engines and mill gearing at Providence, R. I. In 1848, in connection with the Mr. Bancroft of that firm, he commenced the manufacture of machinists' tools and mill gearing, under the firm name of Bancroft & Sellers. In 1853, his brother, John Sellers, Jr., became a member of this firm, and in 1855, when Mr. Bancroft died, the firm became William Sellers & Co. In 1886, the corporation of William Sellers & Co., Incorporated, was established, with William Sellers as president and engineer.

Prior to 1857 bolts and nuts could not be made commercially interchangeable. In that year a bolt machine, the first of its kind, was devised by Wm. Sellers, and constructed by his firm, in which dies, to cut the thread at one pass, and adjustable to size, could be opened and closed while running continuously in one direction, and thereafter ordinary screw bolts and nuts were made interchangeable.

Prior to 1867 the teeth of wheels were cut for special purposes alone. The only power used was that required to rotate the cutter, the movement against the cutter, and its reverse, and the division for the next tooth were all performed by the workman. The cost of such work was so great that the teeth of nearly all wheels, even for fine machines, were cast. In that year the first automatic gear cutting machine was devised by Wm. Sellers, constructed by his firm and exhibited at Paris in the same year, in which the work of the operative was limited to adjusting the wheel for the first cut. The machine then proceeded to cut a tooth, retract the cutter, turn the wheel for the next tooth, and so on until the wheel was cut in less time than it could be done before, and as one man could easily attend several machines, the cost of this work was so greatly reduced that cast teeth were no longer admissible in good machines.

In 1864, Mr. Sellers was elected president of the Franklin Institute of Philadelphia, and in the same year his paper giving the first formula ever offered for screw threads and nuts, was read before that institute, and the formula then offered has since become the standard for the United States. In 1873, Mr. Sellers became president of the Midvale Steel Co., at Nicetown, which he subsequently reorganised, and under his management it became the first successful producer of the material required by the United States Government for its ordnance and small arms.

Prior to this date, in 1868, he had established the Edge Moor Iron Company, for the manufacture of iron and steel structures, and has ever since been its president. This company made all the iron work for the Centennial Exhibition at Philadelphia in 1876, and the steel and iron structural work for the great Brooklyn Bridge at New York. It has now one of the largest plants in the United States, or in the world, for building iron bridges and other structures of iron and steel.

Mr. Sellers was for several years a director of the Philadelphia & Reading Railroad, and since 1866 has held a similar office in the Philadelphia, Wilmington & Baltimore Railroad Company. In 1868 he was elected a trustee of the University of Pennsylvania, —a position which he still holds. He is a member of the Union Club of Philadelphia, of which the Union League is an outgrowth. Of the latter he is one of the corporators, and was for several years a vice-president.

Indefatigable in his exertions to create the Centennial Exhibition, he bore no small share in carrying the project in the direction of assured success, and

was elected vice-president of the Centennial Board of Finance at its organisation, but declined on account of the pressure of business. In 1873 he was elected a member of the National Academy of Sciences, at Washington, and in 1875 a corresponding member of the Société d'Encouragement pour l'Industrie National, at Paris, and in 1889 the honour was conferred of Chevalier de la Legion d'Honneur.

At the Exposition Universelle, at Paris, in 1867, Mr. Sellers' firm received a gold medal, and at the Centennial Exhibition of 1876, in Philadelphia, the judges reported that "this collection of machine tools was without a parallel in the history of exhibitions, either for extent, or money value, or for originality and mechanical perfection." At the Vienna Exposition in 1873, the Grand Diploma of Honour and five bronze medals were conferred upon the firm. At the Paris Exposition of 1889, the highest award, the Grand Prix, was given to William Sellers & Co., Incorporated, together with several medals, and at the close of the exposition, the names of three collaborateurs were requested, to whom, as individuals, diplomas were sent, and to William Sellers in addition, as already stated, the honour was conferred of Chevalier de la Legion d'Honneur.

Current Topics.

THERE are two points in connection with the early history of the steam engine which, so Sir Benjamin Baker remarked in his presidential address to the British Institution of Civil Engineers a short time ago, always appeared to him absolutely astounding and incomprehensible; first, that any mechanic of the period, accustomed all his life to work his lathe by treadle, connecting-rod and crank, should imagine that the application of the crank to a single-acting steam engine was an "invention," and actually secure a patent for the same; and secondly, that a man of Watt's ability and experience should endeavour to circumvent that patent by himself patenting that fearful "back lashing" nightmare, the so called "Sun and Planet" motion. It is not less remarkable that Smeaton about the same time, when reporting on a paper submitted to the Royal Society, of which he was a Member of Council, condemned the crank and fly-wheel because of the imagined difficulty aris-

ing from the stopping of the heavy reciprocating mass at each end of the stroke, and expressed the opinion that the use of the fly-wheel would be a greater encumbrance to a mill than a water-wheel, to be supplied with water pumped up by an engine. There is nothing, therefore, in the history of the development of the steam engine, or in the brilliant career of Watt, to lend support to the theory that the progress of mankind is dependent upon the periodic appearance on the stage of some actor of inspired genius; but, on the contrary, many illustrations are afforded of the fact that men of the highest ability and experience are as apt to be wrong in their forecast of events, and in their estimates of the relative importance of their own or other person's investigations or inventions, as are those of humbler powers.

In the course of the address just alluded to, Sir Benjamin Baker touched also upon that ever-interesting topic,—the interconvertibility of work and heat. Although prehistoric man, he remarked, demonstrated ages ago, by the frictional ignition of dry wood, that work can be converted into heat, the reverse operation, the conversion of heat into mechanical power, was not thoroughly appreciated even half a century ago. It is the latter conversion, however, which chiefly interests the engineer; for although hot bearings and other unpleasant experiences constantly remind him of the possibility of converting mechanical energy into heat, he regards it rather as a nuisance than a blessing. And yet, if we look deeper into the question, we find that after all it is the conversion of energy into heat which accounts for the present existence of the earth itself, and all upon it. It is to the energy liberated by the contraction of the sun's diameter that the world is indebted for heat, since physicists have demonstrated that if the sun had been a solid lump of coal it would have burnt out millions of years ago, and Langley has calculated that all the coal in the Pennsylvania coal fields, though it would last the United States 1000 years, would supply the sun with heat for only one-thousandth of a second. Every square foot of the sun's surface represents some 8000 H. P., and the whole surface, no less than 500,000 millions of millions of millions of horse-power. Indirectly, the engineer utilises a minute friction of the sun's energy, as the rainfall works his water-wheels and turbines, and atmospheric currents his windmills, and wood is used as fuel for his steam engines.

Long before the coal fields of the world are exhausted, there is little doubt the workers on the borderland of engineering will have discovered some plan of tapping the inconceivably great stores of energy around us. The very earth we live on is whirling around like a huge fly-wheel, and if we could only find some way of utilising its momentum we could draw upon it for ages for all the power we want without appreciably affecting the speed of its revolution or the length of our day. It is, indeed, naturally drawn upon now in various things intimately associated with the work of the harbour and dock engineer. The flow of the tide in enormous volume, up and down a river, is accompanied by a vast expenditure of power in overcoming the frictional resistance of the river bed, in the grinding of shingle into sand, and in the transport of sandbanks from one part of the river to another. Even the flow of the water through the sluices of locks involves a loss of energy, as does the working of a tide mill, which latter is one way of utilising, as the others are of destroying, some of the earth's momentum. No true engineer will believe that with so many sources of energy around us the progress of mankind and the work of the engineer will cease with the exhaustion of the coal fields.

It is a matter of wonder for an old time steam engineer to go over a mod-

ern generating engine at this day and observe its many accessories. Taking one of the most advanced, he will find lubricating devices for all joints with motion, the oil all collected by drains to one point, filtered and cleaned, and then returned by a pump to the oil cups to be again circulated automatically. The fixed bearings of high speed engines will be water jacketed to prevent heating, and there will be a world of indicating devices for speed, pressure, vacuum, temperature and time. The condensing water will pass through filters to extract the oil that is entrained from the cylinders, and separators are provided to catch the water in the steam. Most of these things have come from the sea where economy and completeness have outrun land practice in a wonderful degree. In the steam generating elements there are the same additions and elaboration, all tending to economy, but demanding a new class of engineers with a knowledge and training that older practice did not afford,—more knowledge and less work, because all things are automatic, even to firing. Results, too, are of a nature not imaginable twenty years ago, especially in respect to control of speed. One may stand along side of a 1000-H. P. engine when the resistance changes as one to ten, and neither hear nor see, nor even feel a sign of such a change. It is a master achievement in mechanic art and a result of co-operative effort on the part of hundreds, or even thousands, of the most skilled men of the age.

THE apprehension of cheap manufactures in Japan and the sale of such manufactures in European and American markets is now a theme of much discussion, and is also a waste of effort. The Japanese themselves will consume the most of their manufactures and the surplus will naturally be sold for as much as possible; besides, as soon as the circumstances permit cheap production there, the English people and others will take good care to control the investments in skilled manufactures as is now done in India. Captain Noble of the Elswick Works has been in Japan, looking after ship-building, and so, too, have representatives of other companies in England and America, but the chances are that the Elswick Company will do as they did in Italy, if necessary,—put down great works, to be owned, in part, or mainly, by the Japanese Government, and operate such works on joint account.

A LARGE part of the shares in the steel works at Terni, in Italy, are held in England, where the main profits go. This should be the policy of builders generally of ships and ordnance if they want to secure an interest in these manufactures in Japan. The Armstrong Company, having built a large share of the present Japanese Navy, will perhaps stand in favourable position to erect works there, but the Japanese Government is quite competent to judge of advantages offered by other firms. At any rate, no one need be alarmed respecting cheap production in Japan. The wants and wages of the people there will follow in a rapid way. Wages have, it is said, been doubled in some cases within a year and a half.

THERE is ample evidence to prove that the rational heating of buildings was a well-understood art several thousand years ago. In the palmy days of Pompeii's early existence, before its burial under volcanic ashes, the old Roman baths in that town were heated by steam, and in a better and far more scientific manner than is followed at the present time. The walls of the buildings were double, and the steam, at atmospheric pressure, no doubt, was carried up through these walls, all around the rooms to be warmed, bringing them to a temperature approximating that of the steam, and the occupants of the rooms were thus exposed to a radiation of warmth from all directions. In this we have the true theory of heating.

Following, in a measure, this early system, some one in Germany, according to recent account, proposes to build a house of which the frame-work is to be made up of water tubing through which warm water is to be circulated in winter, and cold water in summer, warming or cooling the enclosed spaces as may be prompted by requirements. All the floors and ceilings and walls are to be crossed and recrossed by water pipes, affording heating and cooling surface exactly where theory tells us it should be to give the most desirable results. The building of that house would certainly afford an excellent modern, practical demonstration of the value of those ideal principles.

Apropos of boiler furnace flues, corrugated or otherwise designed to secure stiffness and resistance to collapse, it is worth recalling that it has been the practice on the western rivers in the United States for many years to make the large tubes of the two-flue river steamer boilers, carrying from 175 to 180 pounds pressure, of numerous short sheets, thus securing a great many riveted joints. The double thickness of plates at a large number of points gave what was considered a very serviceable means of guarding against the flattening-out of the flues, and the experience of many years demonstrated the soundness of this view. Engineers from other parts who go west and see a western American river steamer, generally agree that they do not know how to build steamboats there; but the fact is that the boats and the boilers in use there, have grown up as the things best adapted to the country and the circumstances. It may have been that in the earlier days it was difficult to make large sheets and get sound sheets, and, yet, there is strongly presumptive evidence that the point was to get short sheets and plenty of joints for the purpose stated.

An item is now making the rounds which ought to afford factory owners who are wrestling with the smoke problem something to think about. The stack of a German sugar factory, so it is stated, was provided with a soot catcher, and six days afterwards the accumulation was removed and found to figure up about 6700 pounds, which, at a low estimate, ought to amount to about 175 tons in a year. While the correctness of the figures cannot be vouched for and a liberal discount may be in order, it is safe to presume that the result of the experiment was instructive. Soot catchers are not very commonly used appurtenances to steam plants, and probably have little value except as means of complying with local smoke ordinances. But the object lessons which they could teach might lead to very acceptable fuel economies.

The classification of use for steam engines naturally divides itself on the duties to be performed, and natural selection goes on apparently without inductive reasoning on the part of engineers or purchasers. For example, driving the screws of a vessel, of centrifugal pumps and of dynamos are three cases of wide application almost identical in requirements, that is, a nearly invariable resistance, or load, over long periods, the power being delivered generally by horizontal shafts. One type of steam engines should therefore suit all these purposes and do. The result is that we see a gradual trend that way, with the propeller engines leading, and this for good reasons. Such engines are most observed and studied from commercial incentives and by the best steam engineers, and also have the aid of government interests, in the case of war vessels. This law of "selection" will work itself out in any case, but the result is not flattering to human skill which more often explains than originates. Custom is the main impediment. It does not tax the logic of a competent engineer to determine whether inverted steeple framed engines are best adapted to particular

duties, like those named, but a purchaser and also a maker who have always seen well regulated steam engines lie naturally on their sides, can not at once become reconciled to seeing them "stand on their heads."

THERE is an old saying that "the ground is so dry that the rain all soaks in." This, like many other statements of the kind, is accepted on faith when not a fact at all, but quite the reverse. Rain penetrates quicker into earth that is moist, open and expanded, and is repelled and runs off when the earth is dry and covered with dust. Any one who has ditches to look after knows this, and that the first dash of rain after a long dry spell has but little penetration. It is true that a very open sandy soil of a pervious and loose nature will absorb rapidly when dry, but such soil is exceptional. In training water for irrigation, the dry dust on top will form a crust that closes the pores, so to speak, and penetration is slow, but a second flow after the first, when the earth is yet moist, penetrates at once. The repellant quality of fine dust is a fact of daily proof; flour in sacks, sunk into water, remains dry, except a coating on the outside. Similarly a dash of rain on a dusty road nearly all runs off at first.

THE moto-cycle, power wagon and others, that have produced the much-used term "horseless carriage" are lending new vigour to power-impelled hauling apparatus on the Pacific coast in the United States, where traction engines have, for several years past, had a permanent place, even in the mountains. Now it is being discovered that the true habitat of the power wagon is on the arid plains of America, and that petroleum gas is the best fuel for this work. Fuel, water and horse feed are all bulky and heavy compared to oil, and there is great probability of an early use of gas engine freight wagons in the arid California valleys. Thus far all schemes have included more or less tooth wheel gearing and pitch chains, neither of which are desirable elements in a power-driven wagon. The pitch of the chains increases as the joints are ground by the sand, and tooth wheels break, because alignment is impossible without rigidity, and rigidity is neither desirable nor attainable. The problem will be worked out, however, in the near future, but not on the lines indicated by modern traction engines. The valleys of California are wide. A railway can be made through the middle, but this is of little use without feeding laterals from five to twenty miles long, reaching back to the foot hills and up into cañons. Hauling by horses and mules has been beaten over and over again by steam wagons and these will be excelled by petroleum engines when the subject gains some of the attention now directed to pleasure carriages. Adaptation is the point in all these things and that is now going on at a rapid pace.

DISCUSSING, recently, the effect of fire on machinery, before the American Society of Mechanical Engineers, Professor W. F. M. Goss detailed his experience with a considerable quantity of it,—some quite heavy. The building containing the machinery was of brick, with a heavy mill floor, and a ceiled wooden roof with monitor. The heat developed was probably of average intensity for such a building, the fire burning until all of the woodwork had been consumed. But little water was used, and the machinery did not suffer from this. Damage appeared to have arisen from three causes, namely, the falling of the machinery, the falling of the roof timbers and walls upon the machinery, and the action of the heat itself. Machines which were on good foundations did not suffer from the first-named cause, but when there was no foundation, even heavy tools were either broken by the fall or distorted by the combined action of the heat and

of strains resulting from imperfect support after the fall. The results justify the conclusion that in case of fire an indestructible foundation is an excellent life preserver for a machine. Falling debris carried away all lighter attachments, such as lubricators, gauges, small piping, light shafts, rods, levers, hand wheels, projecting brackets—everything, in fact, which offered an abutting surface to the falling masses and which was not strong enough to withstand their impact. There were a few cases where heavier parts also suffered from this cause. Of two six-inch shafts, extending seven feet between bearings, one, carrying an eight-foot fly-wheel, was perfectly straight; the other, having no wheel, was sprung, evidently as the result of a blow. To heat alone is, of course, to be attributed the destruction of woodwork about the machines, and the loss of babbitt from brasses and boxes. From this cause, also, bolts which served to connect different parts of heavy frames were often found loose. Steam-joints of every kind required refitting. Brass bushings which originally had been forced into turned holes to form bearings for shafts or pins were all loose in the castings and tight on the shafts. Castings having very large flat surfaces, either plain or ribbed, were in several cases found to contain fire cracks, but with a few exceptions heavy castings of good design were not injured by the heat alone.

THE results of some low temperature tests of iron and steel, made at the German Imperial Navy Yard, at Wilhelmshaven, have been made public by Professor M. Rudeloff, and add several things worth knowing to the present stock of information on the physical properties of metals. The materials tested included rivet iron, rolled and hammered iron, ship steel, both basic and Bessemer, spring steel, and crucible steel. It was decided to test each material in tension, bending, and compression, and at three different temperatures, these being 64 degrees Fahr., —4 degrees Fahr., and—100 degrees Fahr., the latter being obtained by the use of liquidcarbonic acid. The results showed that, so far as the tensile tests were concerned, a reduction of temperature raised the yield point and ultimate strength, but there was, in general, a reduction in the elongation. The compression tests also showed that the metal became harder, whilst, as regards the bending tests, cooling to a temperature of—4 degrees Fahr. seemed to have little effect on the results, and all the specimens, save those of spring steel and hammered iron, stood bending double at this temperature. At the low temperature of—100 degrees Fahr., however, all the metals, save the rivet and rolled iron, were considerably affected, and would not stand bending through so large an angle as at ordinary temperatures.

WITH all that has been said about paints for ironwork, it may not be amiss to refer briefly to some data on the subject recently presented by Professor J. Spennrath in the *Deutsche Bauzeitung*. Professor Spennrath concludes, from investigations conducted by him, that none of the metallic oxides commonly used combine chemically with linseed oil. The drying process depends exclusively on an absorption of oxygen by the oil, which is facilitated by the presence of the pigment in a purely mechanical way. The value of the different pigments used varies. Thus, zinc white, when used for outside work, rapidly swells to double its previous volume, owing to the absorption of carbonic acid gas and water. Sulphuretted hydrogen will cause red or white lead to act in a similar way, but, when pure, Professor Spennrath considers these two latter pigments satisfactory. Carbon paints are very stable, as is heavy spar, but the covering power of the latter is small. In order to test the relative durability of various paints, sheets of zinc were coated with a number of different

kinds. The zinc was then dissolved away by acid, leaving a film of paint. All these films, it was found, could be destroyed by the action of dilute nitric or hydrochloric acids, while the vapours of sulphuric and acetic acids acted similarly. Alkaline fluids and gases also destroyed the paints rapidly. Pure water was found to be more injurious than salt water, and hence the destructive action of sea water is attributable mainly to the mechanical effects of wash. Hot water was found to act more rapidly than cold. The most important discovery made was, however, the great influence of temperature. Films, similar to those already described, completely lost their elasticity and became brittle when exposed to a temperature of 203 degrees Fahr. There was, at the same time, a large contraction. Similar effects are produced by prolonged exposure to considerably lower temperatures. Blistering Professor Spennrath considered due to the inner coat of paint being so thick that it cannot harden thoroughly before the second coat is applied.

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SPEAKING of prime movers before the Association for the Advancement of Science at London, several years ago, Sir Frederick Bramwell drew an interesting picture of the puny thing that muscular power, whether animal or human, really was when compared with the vast efforts exerted nowadays by machinery. Contrasting a galley, for example,—a vessel propelled by oars,—with a modern Atlantic liner, and assuming that prime movers were non-existent and that this vessel was to be propelled after galley fashion, he proceeded thus :—Take the length of the vessel as 600 feet, and assume that place could be found for as many as 400 oars on each side, each oar worked by three men. or 2400 men, and allow that six men under these conditions could develop work equal to 1 horse-power ; we should then have 400 horse-power. Double the number of men, and we should have 800 horse-power, with 4800 men at work, and at least the same number in reserve, if the journey is to be carried on continuously. Contrast the meagre result thus obtained with the 19,500 horse-power given forth by a large prime mover of the present day, such a power requiring, on the above mode of calculation, 117,000 men at work and 117,000 in reserve, and these to be carried in a vessel less than 600 feet in length. Even if it were possible to carry this number of men in such a vessel, by no conceivable means could their power be utilised so as to impart to it a speed of 20 knots an hour.

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THIS illustrates how a prime mover may not only be a mere substitute for muscular work, but may afford the means of attaining an end that could not by any possibility be attained by muscular exertion, no matter what money was expended or what galley-slave suffering was inflicted. Take again the case of a railway locomotive, in which we have from 400 to 600 horse-power, developed in an implement which, even including its tender, does not occupy an area of more than 50 square yards, and that can draw us at 60 miles an hour. Here again the prime mover succeeds in doing that which no expenditure of money or of life could enable us to obtain from muscular effort.

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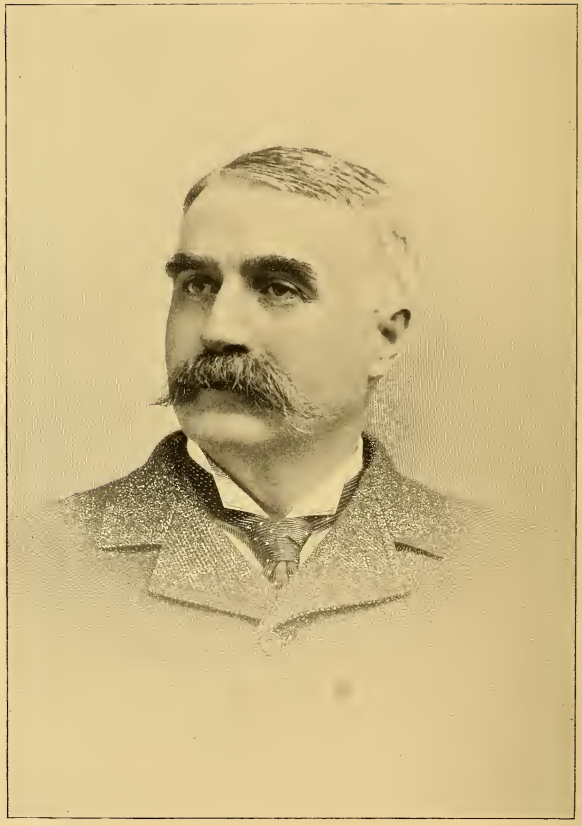
ACCORDING to Sir Benjamin Baker, the charges of powder in guns have, since the time of the Crimean war, increased from 16 lbs. to 900 lbs., the weights of projectiles from 68 lbs. to 1800 lbs. and the energies developed from 1100 foot tons to 62,000 foot tons. Further changes are rapidly following the introduction of the more powerful smokeless powders. The name which in England will ever be honourably associated with improvements in ordnance is that of Lord Armstrong. When in 1882 he described the then condition of the armaments of the coun-

try, he wisely deprecated any idea of finality, and pointed out that the ceaseless labours of engineers must ever lead to progressive changes both in guns and armour. Events have amply justified his warning. Since 1882 the British Navy has been entirely re-armed. The Armstrong muzzle-loading wrought-iron coil gun has been superseded by the breech-loading steel gun of vastly increased power; and whilst in 1882 Lord Armstrong maintained that there was not "any material difference in regard to rapidity of fire between breech loading and muzzle-loading guns, nor would a superiority in this respect on either side be of much value," he himself has since inaugurated the system of quick-firing guns as an indispensable adjunct of every war ship, although in complexity of breech mechanism—which was what Lord Armstrong dreaded in 1882—they compare with the old muzzle loader in much the same way as would a watch with an hour glass. The escape of powder gas at the breech was one of the difficulties at first encountered, and what engineer would have been bold enough to predict that gas at a pressure of over twenty tons per square inch, and at a temperature above that of molten steel, would be effectually sealed by a canvas-covered pad of asbestos fibre, soaked in tallow? And yet that expedient has proved to be a complete solution of the difficulty.

ANENT the various ways in which coal may be, and is, allowed to go to waste in all coal mining regions, it is worth noting that, according to an estimate of the late Eckley B. Coxe, the amount of coal lost in preparation and sent to the culm banks in the anthracite districts of Pennsylvania, since mining began, has been 35 per cent. of the total production, or, up to the close of 1892, a total of 315,700,000 tons. At certain collieries, from the year 1820 to 1883, 20 per cent. more coal had gone to the dirt banks than had been marketed, and from 50 to 75 per cent. of total shipments to dirt banks was not unusual. In view of these facts, the statement that, on the average, during the last fifty years not more than 30 per cent. of the coal mined has reached the place of consumption is not at all surprising.



FROM A PHOTOGRAPH BY SARONY, NEW YORK.

C. F. Brusk

(SEE PAGE 308.)

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CASSIER'S MAGAZINE.

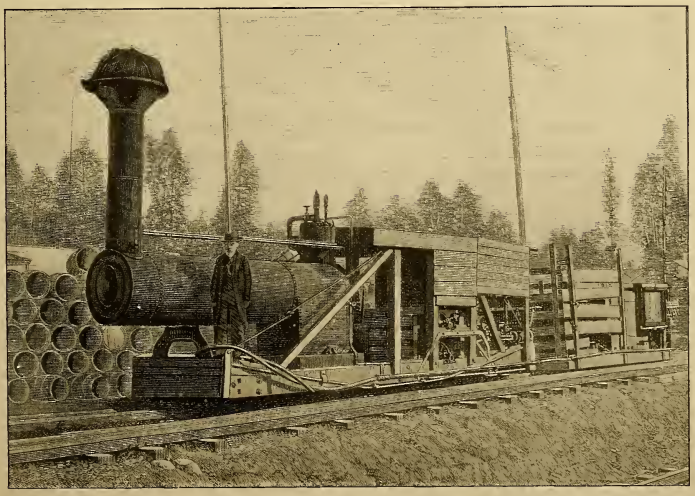
VOL. X. AUGUST, 1896. No. 4.

SOME UNUSUAL FORMS OF LOCOMOTIVES.

By George L. Cark.

THERE should be nothing very remarkable in the fact that since the earliest days of steam propulsion on rails, locomotives have been turned out in almost endless variety, and yet the forms sometimes evolved and dictated either by special and peculiarre quirements, or by inventors' caprice simply, have been sufficiently unique to excite considerably more than passing attention.

Some of these engines, built after rational designs, with good underlying business sense are not by any means freaks. They were made with the view of conforming to unusual conditions which standard locomotive types would not satisfy, and what, therefore, at first



THE BURT WOODEN RAILWAY LOCOMOTIVE AND FREIGHT CAR.

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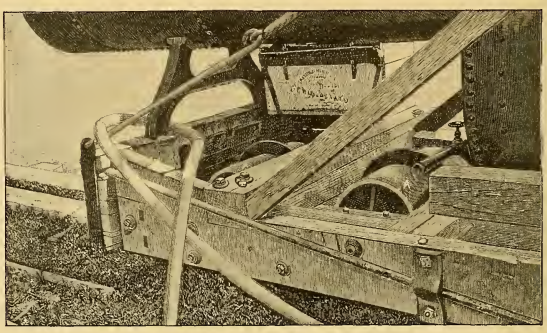
sight, would appear in them as the outcome of unreasoning design, frequently shows itself to be the most expedient in the end. Some, again, are freaks in every sense of the word, intended to accomplish impossible things,—generally the development of abnormally high speeds and powers alike,—by the combination of fearful and wonderful mechanisms. Reference to these would represent but waste of time and space. No measurable useful results have ever been attained by them and their existence furnished evidence simply of the mistakes which may be made under the influence of misplaced enthusiasm.

Of what may be termed the legitimate engines, those shown in the illustrations on the preceding page and on pages 244 to 247, represent several very interesting examples. These illustrations, except that of the pole-road locomotive at the top of page 246, have been reproduced from different numbers of the *Scientific American*, from which journal, too, the appended particulars concerning them have been taken.

The Burt wooden railway locomotive, depicted on the opening page of this article, was evolved by Mr. John J. Burt, who owns a valuable marble quarry and lime kilns at Cienega, Cal., in the United States. To carry the lime to the main railroad line Mr. Burt built a wooden railway about 12 miles long which connects with the terminus of a branch of the Southern Pacific road at Tres Pinos.

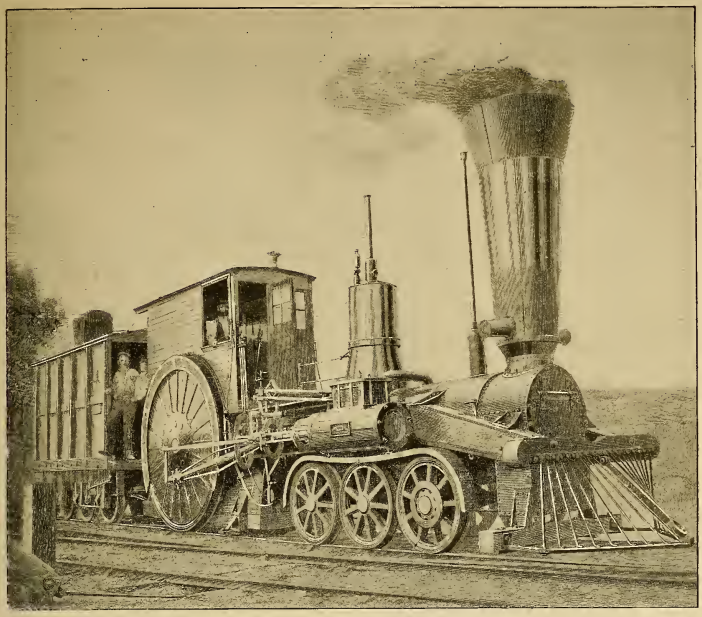
Mr. Burt's road rests on 5-foot ties, 4 by 6 inches square and about 2 feet apart. On these the longitudinal wooden sleepers are laid, made of 3 by 4-inch scantling. Each rail consists of three such pieces, laid side by side, and forming a continuous wooden floor or pathway, 2 feet wide, except that a narrow slot is left in the centre of the floor. On this floor the engine and cars travel, being carried by broad centrally-flanged rollers or wheels, shown very clearly in the illustration on page 244, which represents the front end of the engine.



THE FRONT END OF THE BURT LOCOMOTIVE.

These rollers are a little over 2 feet long and the central flanges on them enter the slot between the wooden rails and prevent the engine from leaving the track. Mr. Burt has also a patent which provides for making the rollers in halves, half of the flange being cast on each section. The sections are then mounted so as to rotate independently of each other and in this way they make the turning of curves easier. Considerable grades exist on the line, but these, it is stated, are readily climbed. No particulars are given of the driving mechanism of the locomotive, but this is probably in the nature of a geared outfit.

The illustration on page 245 repre-

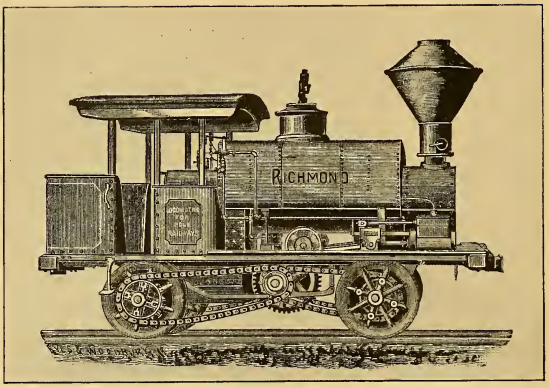


A FAST AMERICAN LOCOMOTIVE OF FORTY YEARS AGO.

sents a locomotive built about forty years ago at the Norris Works, in Philadelphia, for the Camden and Amboy railroad. The original engraving was made from an early photographic print. The *Railroad and Engineering Journal*, in speaking of this remarkable engine, says that while the exact dimensions are not at hand, the cylinders are believed to have been 13 by 38 inches, and the driving wheels 8 feet in diameter.

The forward end of the engine was carried on a six-wheeled truck, and the single pair of drivers was placed back of the fire-box. This arrangement required a peculiar position of the cab which was placed very high and was apparently built without much regard for symmetry or appearance. In fact, it looks somewhat like a switchman's or watchman's house, transferred from the side of the track to the top of the boiler. The same lack of symmetry may be seen in the smoke stack, which was of singularly clumsy pattern. The engine probably burned wood, which was the general fuel for locomotives at that time. The valve motion was all outside; apparently there was an independent cut-off valve, working on the back of the main valve,—a not uncommon arrangement.

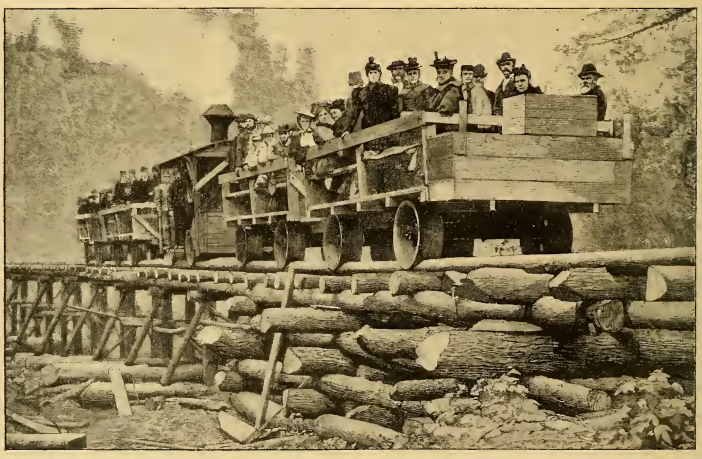
Some of the peculiar features shown did not belong to this engine alone. The spaces between the spokes of the driving wheels were filled with wood, an arrangement which was in use on many of the locomotives of the Camden and Amboy railroad for a number of years. The trussing of the connecting rod was also practised on that road for a long time, and there were locomotives running with side rods trussed in the same way, as late as 1873. The high dome could also be found in quite a



POLE ROAD LOCOMOTIVE, BUILT BY THE POLE ROAD LOCOMOTIVE COMPANY, RICHMOND, VA., U. S. A.

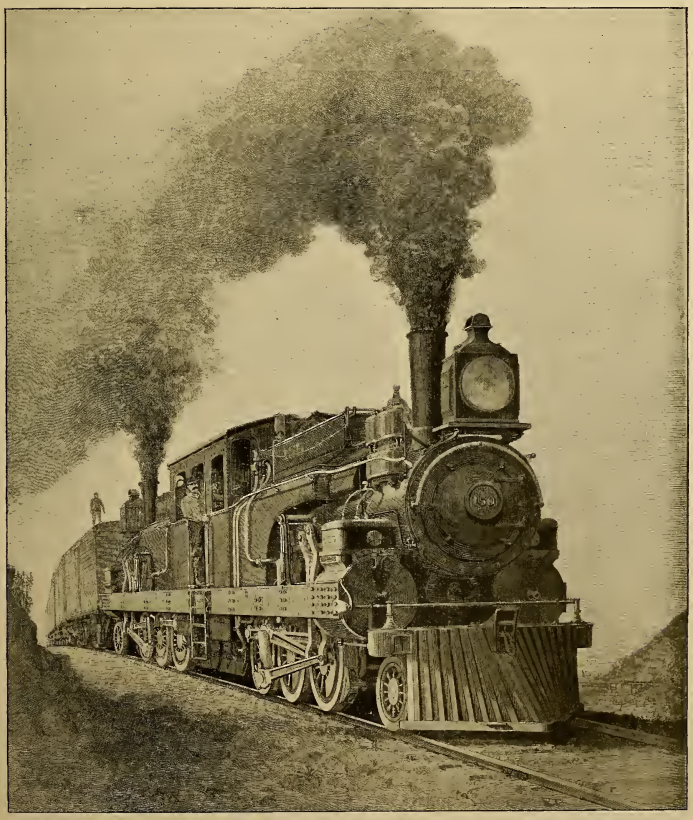
number of engines on the same road. The covered tender, somewhat resembling a small box car, was the pattern in general use on the road, and survived up to 1865 or thereabouts; it was provided with a sort of hood or buggy top on the back end, in which sat a man whose duties were to watch over the train and signal the engineer when anything was wrong, the bell cord passing through his seat.

Some other engines of the same kind were built a little later, either at the Trenton Locomotive Works, in New Jersey, or at the Bordentown shops. These were of a little better appearance, and a more modern type. Some of them had 13x38-inch and some 14x38-

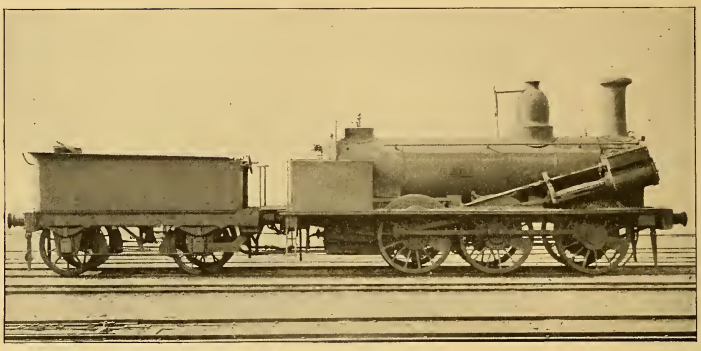


A POLE RAILWAY IN NOVA SCOTIA.

inch cylinders and 7-foot or 7-foot 6-inch drivers. They did some fast running, but had so little weight on the drivers that they could not handle a heavy train; moreover they had an unpleasant tendency to jump the track on sharp curves. These later engines were afterward rebuilt with four drivers of smaller diameter, about 5 feet, one pair placed in front and one behind the fire-box, according to the usual pattern. The long-stroke cylinders were retained, however, and four or five of these engines with 38-inch stroke were in service for some time after the New Jersey lines were leased to the Pennsylvaina Railroad Company. These engines had larger boilers than the one shown in the engraving, and had iron frames instead of the wooden frames which appear in the original Norris type. The photograph from which the engraving in the *Scientific American* was made was taken by Schreiber & Sons, of Philadelphia, from the original Talbo type. The original had been well preserved during the forty-three years since it was taken.



THE JOHNSTONE LOCOMOTIVE ON THE MEXICAN CENTRAL RAILWAY.



AN ENGLISH LOCOMOTIVE OF 1864.

The pole railway picnic illustration on page 246 appeared originally in *Black and White* and is rather more interesting as showing the peculiarity of the road construction proper than the nature of the locomotive used. The line is one of several now in operation in Nova Scotia.

The pole railway is probably the most economical form of steam roadway that has been produced. It is of American origin and has been in vogue in different parts of the country for the past quarter of a century. It is especially adapted for use in forest regions, where lumbering is the principal industry. A first-class, substantial road built of poles will cost anywhere from $75 (£15) to $250 (£50) a mile, according to local circumstances. The poles employed for rails should not be less than nine inches in diameter at the smaller end, and should consist as far as possible of the heart, or they will decay before they wear out.

In the best roads, a bed is hollowed out in the butt end of the pole to receive the small end of the one adjoining, so as to make a secure junction. The bed is made about nine inches in length and deep enough to permit the smaller end to come up flush with the larger. The poles are simply laid on top of the ground, except when the surface is very uneven; dirt is then thrown on each side and trampled down to form a solid bed. After they are in place, they are slightly trimmed down with an adz. When a crook of any kind occurs in the poles, it is of course turned down in laying the track. No cross ties are necessary, as the locomotives and cars are so constructed that they exert no lateral pressure. After a few trains have passed over the road there is no fear of the poles becoming displaced. Curves are made up of a succession of short poles, care being taken that the joints come opposite to each other. The switching is readily accomplished in the ordinary way.

Where heavy grades are encountered, it is the practice in some localities to place the locomotive in the middle of the train, and at the particularly steep grades to cut away half the train, push up the other half, uncouple, and return for the remaining cars. In this manner, trains of six loaded cars have been taken over grades of 700 feet to the mile with the use of only one locomotive. The wheels of the cars and locomotives have very broad treads, deeply grooved, so as to fit the curvature of the poles. The illustration at the top of page 246 will help to give a pretty fair idea of the general characteristics of a locomotive used on a pole line, like that just described.

A most interesting engine is that shown on page 247, designed several years ago for the Mexican Central rail-

way by Mr. F. W. Johnstone, superintendent of motive power of that railway, and built by the Rhode Island Locomotive Works at Providence. It was made for special service in drawing freight trains over heavy grades and curves on certain parts of the road, and in appearance is much like a couple of locomotives, backed up together, with the two cabs joined. Flexibility sufficient to go around sharp curves with the least frictional resistance was gained by securing the driving wheels in a truck which is free to move in a line different from that followed by the main frames.

The cylinders and boilers are carried on the main frames, separate from the driving wheel truck. As the cylinders are not in line with the driving wheels in rounding curves, it was necessary to have a special method of transmitting power from the cylinders to the crank pins. This was secured in a very ingenious way through levers that transmit the power and compensate for the varying distances between the pistons and the crank. But for this compensating arrangement, it would be necessary to give the engine so much cylinder clearance that the loss of steam would be very great.

The power transmitting levers are at the back of the cylinders, connected at the top by a short link, and the bottom ends are pinned to the front ends of the main rods. There are two of the latter, one connecting with a crank pin, and the other with a return crank. The piston transmits motion to the back one of the two levers and that gives motion to the front lever which is fulcrumed securely to the frame near its centre.

TRAM ENGINE OF THE GREAT EASTERN RAILWAY COMPANY, ENGLAND.

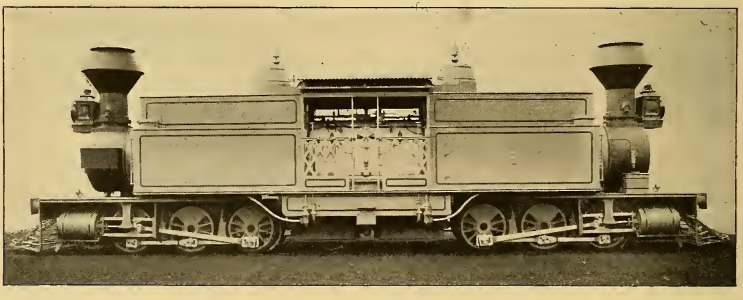
The engines are compound, with annular cylinders, the high-pressure cylinder being in the middle, and the low-pressure cylinder outside. The former is 13 inches in diameter, and the latter 28 inches, the stroke being 24 inches. It was calculated that the cylinder ca-

REGULAR EXPRESS ENGINE OF THE LANCASHIRE AND YORKSHIRE RAILWAY, ENGLAND, AND TRAMWAY ENGINE USED IN THE COMPANY'S WORKS.

pacity of each pair of cylinders would be equal to a 19x24-inch simple engine. Steam is carried in the boilers at 180 pounds. The engineer sits on one side of the cab with all the necessary apparatus for working within easy reach. On the other side the fireman pours in the fuel through side doors. A coal passer is necessary to aid him.

An old English engine of unique pattern is shown at the top of page 248. This was built early in the sixties by Messrs. Fossick & Hackworth, probably for the Llanelly Railway and Dock Company, as it was sold by that company to the Carmarthen and Cardigan Railway Company in 1873. The engine came into the possession of the Great Western railway when that company took over the undertaking of the Carmarthen and Cardigan Company in 1881. It was then worn out and never worked for the Great Western, but was broken up in 1889. The engine had outside cylinders, placed obliquely on the sides of the smoke-box. The connecting rods were coupled to the trailing wheels. The tender had a wooden under frame and was probably not the one originally supplied with the engine.

One of a number of small engines which are in use in the works of the Lancashire and Yorkshire railway, at Horwich, England, is shown at the top



A FAIRLIE LOCOMOTIVE, BUILT FOR MEXICAN SERVICE BY MESSRS. NEILSON & CO., GLASGOW, SCOTLAND.

of page 250, and is perhaps of special interest at this time when so much is being said about railways for dealing with agricultural produce. Six miles and a half of tramway lines are laid throughout the Horwich works and are operated by these engines, carrying material between the various buildings. They are built to run on an 18-inch gauge, and have cylinders 5 inches in diameter with 6-inch stroke. The wheels are 16¼ inches in diameter, and the wheel base measures 2 feet 9 inches. The extreme width of the engines is 3 feet. They work with 170 pounds boiler pressure and have a tractive power of 1412 pounds, or about 9¼ pounds per pound of effective pressure per square inch of piston area. When full and in working order each engine weighs a little over three tons. The relative proportion between one of these engines and the regular main line express engine (7-foot 3-inch four wheel coupled) of the company is well shown in the illustration which shows the two engines side by side.

A remarkable type of engine is found in the double Fairlie locomotives which were specially designed to run on one section of the Mexican railway, where there are inclines as steep as 1 in 25. The engines, which were built by Messrs. Neilson & Co., of Glasgow, Scotland, are exceptionally heavy, and when fully loaded with water and fuel, scale ninety-four tons, a weight which is wholly available for adhesion. Each bogie is fitted with two cylinders, and is an engine complete in itself, steam being supplied from the boiler which is common to both.

The leading dimensions of the engine are:—

Cylinders	16	inches diameter
"	22	" stroke
Wheels	42	" diameter
Heating surface in tubes	1,532	square feet
" " in firebox	180	" "
" " total	1,712	" "
Area of grate	33	" "
Wheel base of each bogie	8 feet	3 inches
Wheel base total	32 "	5 "
Distance of centres of bogie pivots	22 "	8 "

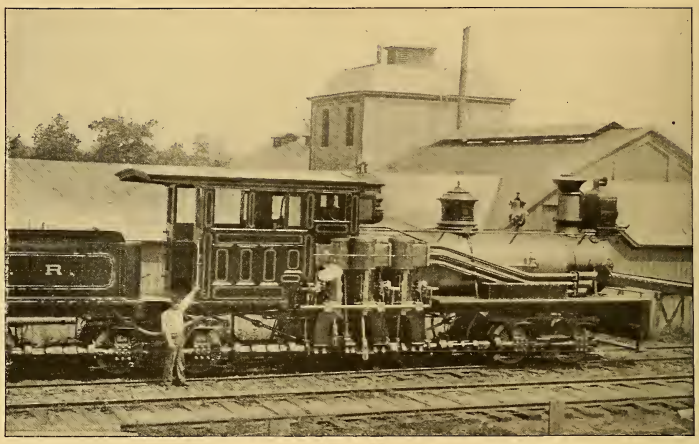
The working boiler pressure is 165 pounds, and the tractive force 268 pounds for each one pound of effective pressure in the cylinders. Taking this at 146 pounds, the total tractive power or pull on the draw bar is about seventeen tons.

This unusual type of locomotive seems to satisfactorily perform the particular class of work for which it is designed, as shown by the large number which Messrs. Neilson have constructed. Three lots have already been finished and sent out to Mexico, the first in 1882, the second in 1889, and the third in 1891. A fourth lot is being constructed, in which, with the addition of the Westinghouse brake and other improvements, the weight in working order will be increased to probably ninety-six tons.

Accidentally one of these engines was subjected to a test which far exceeded in severity any one which could have been devised by a board of trade or other inspector. An account of the occurrence may prove interesting alike to the locomotive engineer and to the general reader. Something went wrong on one occasion with the brake on a train drawn by one of the Fairlie engines, and the train, which was on a decline, consequently ran away. Some of the wagons were derailed and smashed up. The engine then broke loose, and dashed off on a stretch of six or seven miles down the slope, over reverse curves of from 350 to 400 feet radius. It reached the bottom in safety and was there pulled up. The speed, which was far beyond the highest rate contemplated by the designers, is believed to have been as high as 70 miles an hour. One of the curves traversed is more than a semi-circle, and is of about 400 feet radius, while the gradient there is even worse than 1 to 25.

Having regard to the terrific speed at which the motion must have been working and the swaying which the engine got on the run, the fact that nothing gave way speaks volumes for the soundness of the material and the excellence of the workmanship. The officials of the railway company consider that the incident forms one of the finest testimonials which the Messrs. Neilson could have received.

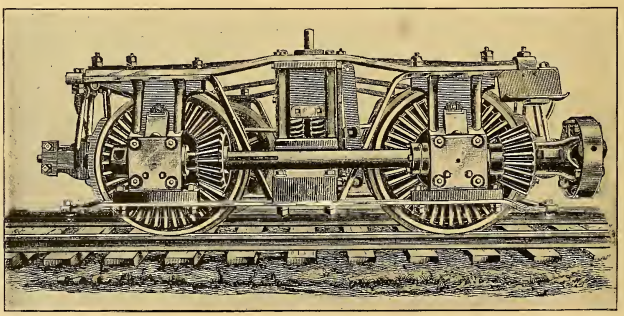
The Shay locomotive, shown at the



THE SHAY LOCOMOTIVE, BUILT BY THE LIMA LOCOMOTIVE AND MACHINE COMPANY, LIMA, O., U. S. A.

head of this page, is a form of geared engine which has proved of excellent service in lumber regions, hauling heavy loads over steep grades and on poor roads. Mr. E. Shay, the inventor of this engine, was engaged in the pine lumber industry in Michigan, in the United States, and conceived the idea of a geared locomotive for hauling logs. He built his first locomotive on an ordinary flat car and it became at once apparent that he had made a useful invention, the engine having a very short rigid and a very long flexible wheel base, enabling it to work successfully on the sharpest curves.

As finally developed and now built, the engine rests on two four-wheel, centre-bearing swiveled trucks, the wheels of which are driven by bevel gearing, attached to the right hand wheels of each truck. The pinions which mesh with these are carried on a shaft extending from one axle to the other of each truck. Power is transmitted through a flexible shaft extend-

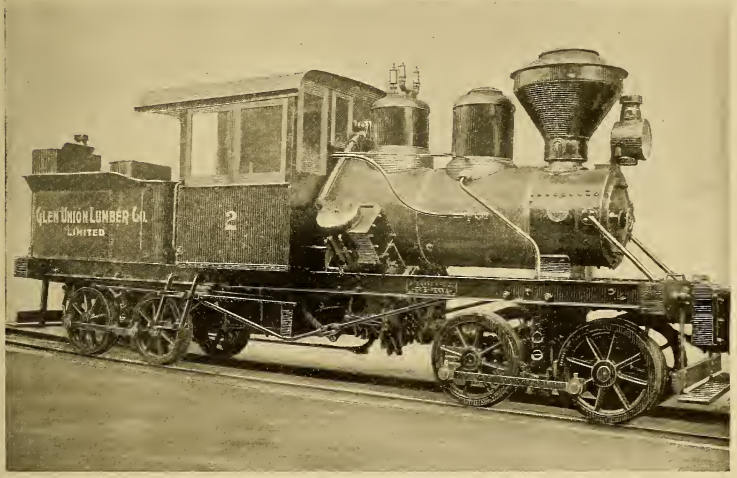


ONE OF THE SHAY LOCOMOTIVE TRUCKS.

ing from the engines. The latter are vertical and are on the same side of the boiler as the pinion shafts. The boiler is of the usual locomotive form, and, in order to balance the weight of the engines, is set a few inches over the left side of the frame. The machinery is all on the outside. A cab is provided for the engineer and fireman, with a water tank and coal box in the rear, so

building the drainage canal for the city of Mexico, are using one of these engines successfully on a wooden track, with heavy grades, varying from 6 to 8 per cent., and some as much as six miles long.

All the working parts of the locomotive are of cast steel; the gears are mounted on a common steel frame and are placed in an oil tight case which is



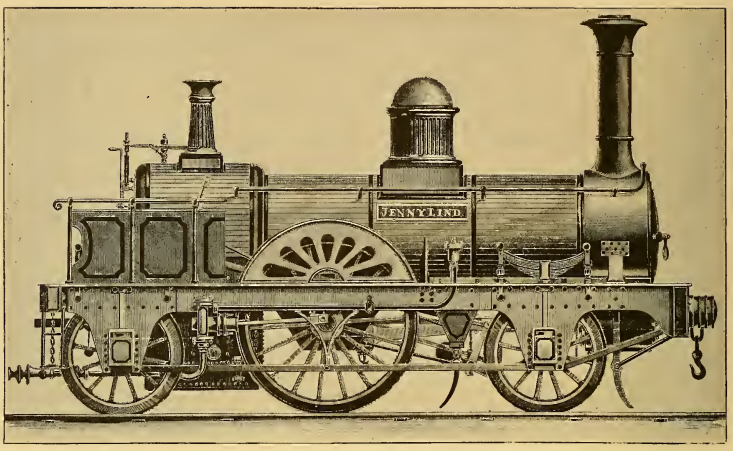
THE HEISLER LOCOMOTIVE, BUILT BY THE STEARNS MANUFACTURING COMPANY, ERIE, PA., U. S. A.

that the whole outfit has the general appearance of an ordinary locomotive. On regular metal track roads, as well as on wooden tramroads, engines of this make have yielded most creditable performances.

The Heisler locomotive, shown on this page, is another form of geared design which is giving a good account of itself. It is built in all sizes from ten to forty tons, and there are now under construction by the Stearns Manufacturing Company two thirty-ton engines and one of forty tons for prominent lumber firms. The main features of the design are very well shown in the illustration. Messrs. Reed & Campbell, a firm of English engineers, who are

filled with lubricant before being sealed. This insures good lubrication, freedom from dirt and dust and safety. The gears are in halves, and can be removed if necessary by the engineer with the ordinary tools found in any kit.

One more example, and this collection of odd locomotive data will have reached the limit of space here allowed. This last example, given on page 255, has been reproduced from *The Engineer*, of London, and represents the *Jenny Lind* around which much historical interest centres and which was, in a very large measure, the forerunner of the standard type of English locomotive. Of the origin of the design, which is very instructive, *The Engineer* gives



A PASSENGER ENGINE ON THE MIDLAND RAILWAY, ENGLAND, IN 1848.

the following particulars, made available through the courtesy of Mr. David Joy, under whose supervision it was worked out:—

In 1846 Mr. Joy was chief draughtsman at the Railway Foundry, Leeds, Mr. E. B. Wilson being head of the firm. Mr. John Gray was locomotive superintendent of the London and Brighton railway. At the end of November, 1846, Mr. Joy was sent to Brighton to see him about an order for ten locomotives. Mr. Joy was employed for some time taking tracings from Mr. Gray's drawings and getting particulars. Then he travelled all over the line on various types of engines, among others, the curious locomotive with two pistons moving in opposite directions in each cylinder, designed by Bodmer. This engine some years subsequently ran off the road on the Lewes branch, killing both driver and fireman. The engine designed by Mr. Gray had six wheels, single drivers, 6 feet in diameter, leading and trailing 4 feet, cylinders 15 inches by 24 inches, boiler 10 feet long by 4 feet 1 inch diameter. The fire-box was square, 3 feet 4 inches by 3 feet 4 inches, and 4 feet 9 inches deep. There were 700 square feet of tube surface, and 79 feet of fire-box, and 11 square feet of grate; pressure 100 pounds. There were two domes, both alike with square bases and lever safety valves. This engine was built by Hackworth, and ran very well, easily making forty miles an hour with heavy trains. There were on the line certain long boiler engines. These were much favoured, but those on the Brighton line rolled fearfully.

Mr. Joy endeavoured to arrive at some conclusion as to what engine really would suit the line best out of all the types in use. He returned with the tracings of the Gray-Hackworth engine to the Railway Foundry, and began new drawings for two engines, Nos. 60 and 61. These had scarcely been begun when Mr. Gary left the Brighton line. The drawings were stopped, and orders were given that the Railway Foundry should submit designs for a new type. By Mr. Fenton's directions Mr. Joy began to scheme on the lines of the last locomotive built; one for the Leeds and Dewsbury line, with a boiler 11 feet 6 inches long, outside cylinders, drivers far back, and trailing wheels behind the fire-box, and with as much heating surface as possible.

About a dozen engines were sketched, and none of them appeared satisfactory. Mr. Joy went home on Saturday afternoon with his mind full of his subject, and in the evening he began scheming again, and prepared a sketch of the engine subsequently known as the *Jenny Lind*, so-called after the famous singer whose name was just then in every one's mouth. At that time a low centre of gravity was deemed essential to steadiness. The *Jenny Lind* had inside cylinders, 15 inches by 20 inches, and single driving wheels, 6 feet in diameter.

There were 800 square feet of surface, of which 80 were in the fire-box. The cylinders had the slide valves between them. The valve gear was the Stephenson link, the link being hung from the middle at one side only. Great care was taken to provide a free exhaust. The pressure was 120 pounds, and the calculated weight full twenty-one tons.

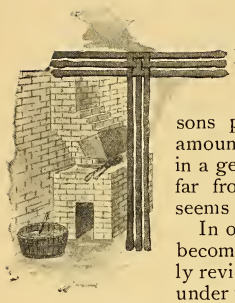
On Monday morning Mr. Joy took his sketch to the works. It was at once approved, and he began detail drawings; various parts were strengthened, and the finished engine weighed full twenty-four tons. This was the origin of the *Jenny Lind* type, which remained for years the standard engine built by the Leeds Railway Foundry Company. It was the first high-speed really economical engine, the economy being due to excellence of workmanship and good proportion of parts, but mainly, no doubt, to the then excessive pressure carried in the boiler. To Mr. James Fenton is apparently due the credit of making the advance from 80 pounds or 90 pounds, then usual, and 100 pounds, then exceptional, to 120 pounds. Mr. Joy says that he endeavoured to combine in the *Jenny Lind* all the good points of the Gray and various other engines. The *Jenny Lind* constituted a remarkable advance on what had gone before it, and held its own for years to come with what followed it, and this is not wonderful when we consider what the performance of the engine was in actual work.

In May, 1847, the first *Jenny Lind*, No. 60, on the Brighton line, was completed. The boiler was lagged with mahogany. The first run was made with it to Wakefield *via* Normanton, and returning, the engine was nearly run into by the Manchester mail train. The *Jenny Lind* was so much liked, that the Railway Foundry got numerous orders, and for some time built "Jennys" at the rate of one per week, a remarkable achievement in those days. A more powerful type of this engine was constructed with cylinders still 15 inches by 20 inches, but with four driving wheels instead of two, the diameter being reduced to 5 feet 6 inches, the trailing driving axle being as close to the fire-box as possible. In August, 1847, the last of the ten "Jennys" for the Brighton company was finished. It had 6-foot 3-inch drivers and 1000 square feet of heating surface.

The illustration is a reproduction from a photograph of a *Jenny Lind* which was on the Midland railway.

BRAINS IN MODERN STEAM ENGINE BUILDING.

By W. D. Wansbrough.



THE assertion that steam engines can be made by persons possessing no great amount of brains, if taken in a general sense, is not so far from the truth as it seems at first sight.

In order to realise this it becomes necessary to briefly review the circumstances under which steam engines of moderate size are now manufactured in quantities in modern factories. I think I shall have no difficulty in showing that the skilled workman of to-day is as much a product of the times as the machines he is so largely occupied in tending ; and that, though the operative of to-day may be individually as intelligent, undoubtedly far better educated, and an all-round better citizen than his predecessor of a previous generation, yet, so far as his actual work is concerned, brain power is being practically superseded by steam power.

I make this rather sweeping statement deliberately and with a sincere conviction that, disguise it how we may, while our machines are becoming almost human, nay, almost superhuman in their powers, the workman himself is, as a matter of fact, more and more nearly approximating to the condition of an automaton,—a wage-earning machine. He is living upon the brains of dead-and-gone inventors, pioneers of mechanical industry, like Maudsley, and Bramah, and Whitworth,—intellectual giants, whose legacies enable us, as it were, to eliminate the quality of hardness from iron and steel, and to cut these and other metals into what forms we will, without even the appearance of effort.

The mechanic of the present day gets through his day's work without the necessity of exerting himself to more than the most trifling extent, either bodily or mentally. I quite admit that this is a gain, on the whole, for all the parties concerned ; for the workman, because, though his work is lightened, he earns better wages, and is at liberty to devote his intelligence to doing good for himself in other ways—his status is raised ; he has time and opportunity for rest and rational recreation; his day's work is not, as formerly, his day's sole occupation. It is a gain, too, for his employer. A single man's production is now from five to fifty times what it was in the early days of mechanical engineering. It is good for the community at large,—directly, because the increased facility of production lessens the price at which good articles may be purchased ; and, indirectly, because the man, relieved from exhausting toil, is a more valuable citizen than he who has no leisure to devote to the improvement of himself and his fellows.

I must not, therefore, be understood as conveying a reproach when I assert that the mechanic of the period has his mental as well as his bodily labour performed for him.

At the root and foundation of all steam engine construction are two elemental forms—the flat surface and the screw. We shall probably never know under what difficulties our early predecessors laboured in the endeavour to produce true planes and accurately pitched screws. The mechanic (or machine attendant as he might perhaps be more appropriately called) of to-day would probably reply, if asked how the first screw was produced, with some feeling of pity for the ignorant ques-

tioner, that of course it was cut in a screw-cutting lathe, or in a screwing-machine.

Was it? A few months ago an historical engine factory was broken up and sold piecemeal under the auctioneer's hammer. This was the cradle and nursery of the steam engine, for it was built and equipped by a respectable, but somewhat old-fashioned, firm of engineers, called Boulton & Watt, somewhere about a hundred and twenty years ago.

Evidently this firm of new-beginners was not so well up in screw-cutting as our flippant friend yonder, for it was found at that sale that one, at least, of their lathe-screws had actually been cut out of a round bar by sheer force of hammer, chisel, and perseverance, finished dead true, and pitched accurately, and its nut in halves to match by hand with a file. Our friend could have done the job for them in about a fiftieth part of the time.

This historical screw is probably the parent or ancestor of countless multitudes of other lathe-screws, and when we reflect that any original error in pitch would be faithfully transmitted, copied or reproduced into every screw generated from it, directly or indirectly, we can appreciate the knowledge and foresight which led the firm of Boulton & Watt to originate a true screw for their own use regardless of trouble or expense, in this painstaking manner.

Nearly forty years afterwards, Maudsley practised a more certain and less cumbrous method of generating original screws. "It consisted in the employment of a knife-edged, hardened steel instrument, so arranged as to be set at any required angle, and its edge caused to penetrate the surface of a cylindrical bar of soft steel or brass. The bar, being revolved under the incisive action of the angularly placed knife-edged instrument, thus received a continuous spiral groove, cut into its surface. It was thus in the condition of a rudimentary screw, the pitch or interval between the threads being determined by the greater or less angle of obliquity at which the knife-edged instrument was set with respect to the axis of the cylindrical bars revolving under its incisive action.

"The spiral groove, thus generated, was deepened to the required extent by a suitable and pointed hard steel tool, firmly held in the jaws of an adjustable slide, made for the purpose as part and parcel of the bed of the machine; and in order to generate or produce right-hand or left-hand screws, all that was necessary was to set the knife-edged instrument to a right or left hand inclination in respect of the axis of the cylindrical bar, at the outset of the operation. The descendants of screws, originated by Henry Maudsley in this manner, are to be found in every workshop throughout the world where first-class machinery is constructed." This concise and interesting description is taken from the autobiography of another remarkable tool maker, James Nasmyth.

A few years ago an original screw, only, I believe, about five feet long, was made in London, its primary object being to produce the screws of astronomical instruments. The cost of this 5-foot screw was estimated at £200. What was it that cost the £200? The value of the material in the screw is absolutely negligible; the manual labour involved is comparatively trifling. How was the money spent? In brains!

The method by which this master screw was produced is too long for insertion here, but, broadly speaking, it consisted in, firstly, the careful microscopic observation of, and detection of the errors of pitch in, the finest leading screw which could be procured. Secondly, the amount of error thus determined at very frequent intervals along the leading screw, was plotted out in a curve of the full length of the screw. A steel template, made in the form of this curve, affixed to the bed of the lathe, so acted upon the screw of the compound rest, as the saddle moved along, that the cutting tool was here slightly retarded and there slightly advanced in its progress, the effect being to compensate for each error as it occurred.

Whether the screw thus cut was, in its turn, made the leading screw of the

lathe, and a second screw cut under the same precautions, I do not remember; but it is evident that if this process were carried out two or more times, a very near approach to a perfect screw might be expected.

But for many long years after the time of Maudsley, while screws of quite reasonable accuracy were attainable in every engineer's workshop, there was a sad want of uniformity in pitch and in diameter, as well as in shape of thread. In fact, the more time and attention a man paid to the establishment of a system of screw-threads which should rule throughout his own factory, the less inclined was he to approximate his own practice to that of other firms engaged in the same business. Hence, as was quite to be expected, the different pitches and diameters in use for nominally corresponding screw-threads, were like the stars of heaven for multitude. I am not now speaking of the "bad old times" when every bolt about a machine had its own particular nut, numbered to suit, and which could only be approached by that detestable invention, the shifting spanner, or monkey wrench. The want of uniformity in the practice of different makers of engines and engineers' tools was, however, nothing short of a nuisance to the user.

In this emergency arose Joseph Whitworth, whose uniform system of screw-threads and nuts is now the only standard in use among English engineers. We who live in these times are so accustomed to see absolute interchangeability in screw-threads and nuts, by whomsoever made, that we find it difficult to realise the confusion that existed in pre-Whitworthian days. Now we can catch a ploughboy, put him to work at a screwing-machine, and the only exercise for his brains he is likely to find is the problem of how many gross he can screw per day, and perhaps the laborious mental effort of computing how much it will amount to at, say, four pence three farthings per gross.

Or, you can go a step higher in the mechanics' scale—to the turner. This is a man who has served an apprenticeship to the occupation of inserting a tool, ground to a traditional form, into a slide-rest, and so manipulating his self-acting machine that it either forms a screw, or a cone, or a cylinder, or a flat surface, or a nut, or any one of the endless variety of forms which this most versatile of engineers' tools, the lathe, is capable of producing.

It is no reproach to the men who practise the craft of the turner to say that the very perfection of the tool which they manipulate, and of the system under which they are employed, has relieved them, as a body, from the necessity of unduly straining their intellectual powers. A man may just be able to compass the rule-of-three sum which fixes the ratio at which his lathe-spindle should be geared to his leading-screw, to enable him to cut a screw of a given number of threads per inch, but even this is becoming next door to obsolete, for most lathe makers nowadays, having calculated these ratios once for all, affix to the machine a list or table to which the workman can refer and thus save himself the abstruse problem I have mentioned.

Again, in many modern engineers' shops the tools used in the lathes and other machines are upon what is known as the tool-holder system, which means that the turner, or planer, or shaper, has his tools ground and kept in order for him, thus saving the loss of time incurred by leaving his machine in order to grind his cutting-tools. His scope is further reduced, in all probability, if he be employed in a large factory, by the circumstance that it is found to pay both master and man better to keep the lathe employed upon repetition-work from one year's end to another.

Thus, a man may, during the whole of his active life, be continuously engaged upon the production of one article, nay, frequently upon only one size of one article. Of course he attains a certain degree of expertness in machining this particular article, but, according to my own observation, not, as a rule, to such a marked degree as one would be led to expect. Surely this machine-made workman, the ultimate product of the system of specialising

the man to the work, is a case in point, that no great amount of brains is needed in making a steam engine.

In the days of Boulton & Watt, brains were as necessary as hands to the workman, and every one, down to the humblest, had his share in the production, and, not impossibly, some liberty in the suggestion of points in the design also, of each new mechanical wonder turned out from their Soho Foundry.

"We are," writes Matthew Boulton to the celebrated Smeaton, himself an engineer, and the successful builder of the third Eddystone Lighthouse (now re-erected as a monument to his memory at Plymouth), "we are now systematising the business of engine-working. We are training workmen, and making tools and machines to form the different parts with accuracy and at a cheaper rate than can possibly be done by the ordinary methods of working. Our workshops will be of sufficient extent to execute all the engines which are likely to be soon wanted in this country, and it will not be worth the expense for any other engineer to erect similar works."

Boulton was a better engineer and man of business than prophet. The Soho Foundry which was to be equal to the supply of all the steam engines required for England, has ceased its activity and the buildings have been converted to other uses. But every steam engine at work to-day records the imperishable genius of James Watt and the immeasurable benefits which his inventions have conferred upon the human race.

It took brains in those days to produce a flat surface upon a piece of metal. After days of laborious chipping, and filing, and grinding, an approximately level surface was produced, and was, no doubt, contemplated by the successful artificer with a feeling that he, too, had produced something worth his master's approval. Nowadays the most ignorant labourer, utilising the brains of one man, Henry Maudsley, the founder of the present great firm of Maudsley Sons & Field, can, without unduly fatiguing his own intellectual powers, produce in a tenth of the time a flat surface which would have inspired Watt or Smeaton with admiration.

And so, throughout each department in this modern engine factory the most casual spectator cannot fail to observe how the process of natural selection has differentiated thought and action. The man who thinks does not work—at least not with his hands. Probably he is regarded by the man who works, but does not think, as having an enviable sinecure.

Labour-saving machines, each the embodiment of some inventor's thought and care, many of them masterpieces of mechanical skill, abound on every hand, and are adapted to every conceivable purpose. Every detail in the standard patterns of prime movers, steam, gas or oil-engines, made in this place, is thought out and designed with a view to being dealt with by one or other of these self-acting machine tools we see around us. Dimensions, gauges, templates, all are prepared. Thought is as carefully economised in as labour. A design or a process, once thought out, remains, and continues in force until superseded by some better method. Each workman has his own appointed work, his own prescribed method of doing it, from which he is expected not to deviate. In short, his thinking is done for him, and he is paid, not for his brains, but for the work of his hands.

Lest I should be accused of overdrawing this picture, let me hasten to add that promotion from the ranks is the unfailing reward of conspicuous ability. The eyes of those in authority are constantly on the alert to bring forward the man who shows signs of exceptional ingenuity or of administrative power. If this should meet the eye of any among the great army of workers who are desirous of improving their position, let me impress upon them with whatever force my words may carry, that although application and industry are essential characteristics of the man marked out for advancement—in the sense that a lazy or inattentive workman is hopelessly out of the running—yet, a man may be

sober, punctual, attentive, and a good workman, but, unless he exhibit traces of other qualities than these—a workman he will live and die. His reward will be found in his being given the best class of work in his particular line, in being paid at the highest current rate of wages, and in the esteem and respect which such qualities never fail to earn from his fellows, his superiors in grade, and his employers.

But he will never be promoted—never be put in responsible charge of a section or of a department, and he will possibly experience the mortification of seeing some much younger man put over his head, into the position to which, by seniority, he is clearly entitled. What is it that he lacks? Brains? No! not even that, necessarily.

The man who outstrips him in the race may be no better stocked with brains than he, but he has learnt to make use of what he has. He is ambitious to lead instead of following, and by observing what he sees, and reasoning upon what he has observed, he has developed his faculties.

He sees a process that might be improved upon. The result of his improvement will be that the price of the work will be reduced by one-half. The simply sober and attentive workman, who cannot see an inch beyond his nose, would deprecate any interference or alteration leading to such a result, on the ground that he would have to pass double the number of articles through his hands to earn the same money, and would be simply benefiting his employer. Short-sighted mortal!

The younger man gets his invention or suggestion adopted, perhaps with hardly a "thank you" from his foreman, and as nothing succeeds like success, keeps his eyes on the alert to see whether he can not hit upon something else. In a shop where men and boys are grouped into gangs or contracts, he applies to have a couple of boys grouped with him, and takes charge of a small contract. To his own immediate pecuniary loss he devotes himself assiduously to teaching these boys the best methods of doing their portions of the work. The temporary loss is soon made up by the increased output from the boys, and he feels able to undertake a more important contract.

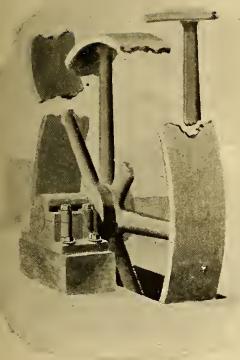
By and by he is looked upon as a young fellow who "can't be kept down." He is an inventor, he is an administrator.

"Remind me about him the next time there is a vacancy," says the manager or the employer—and "he puts on his coat," and the ranks of manual workers, like Joseph's brethren, "make obeisance unto him."

Such are the lines upon which the workman who desires to rise should proceed. I make no apology for having devoted so much space to discussing this question—even at the risk of turning all our workmen into foremen prematurely. There is always "room at the top," and for men who have cultivated their brains there is an ever-increasing demand.

FLY-WHEEL NOVELTIES.

By Harry E. Campbell.



THE one part of an engine which does not in recent years appear to have received the attention that its importance seems to warrant is the fly-wheel. The wheels under construction to-day are the same in all essential features as those put on engines five or ten years ago.

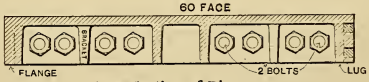
The cast-iron wheel has undoubtedly reached the limit of development, and that no further improvements can be looked for in them is universally acknowledged by engineers. The many accidents caused by the bursting of cast wheels prove that such wheels are unsafe and unreliable, and unfortunately the larger and heavier the wheels are built, the smaller is the factor of safety employed.

All other parts of an engine are designed so as to safely withstand a much greater speed than the normal, but the fly-wheel has usually very little surplus strength. The consequence is that when the engine speeds up from any cause, the fly-wheel is almost invariably the first to give way under the strain. Fig. 1 shows a section of a modern fly-wheel, and from the careful study of fourteen large wheels the writer has decided this to be one of the best cast wheels in use.

This wheel is well designed and constructed, making 80 revolutions. At 94 revolutions the strain becomes 1000 pounds per square inch in the flanges of the rim. In this calculation it is assumed that the arms will carry one-third of the stress due to centrifical force and that the other two-thirds are resisted by the rim. This makes the factor of safety one-sixth. This wheel is a good illustration of the weakness of cast-iron in fly-wheel construction. Perhaps it may be said that the tensile strength of cast-iron is over 1000 pounds per square inch. This is generally true, but the writer believes it to be the utmost limit of safety in cast wheels.

All foundrymen know that it is impossible to get uniform results from cast-iron, and of two castings, put up by the same man, moulded from the same pattern and poured from the same ladle of iron, one may prove to be perfect, while the other, looking equally well on the face, may be honeycombed

Part of Rim.



Cross Section of Rim.

FIG. 1.—A MODERN FLY-WHEEL DETAIL.

in such a manner as to make it worthless. The proof of this can be found in every scrap pile.

The weakest point in a built-up wheel is undoubtedly in the connections of the rim. This is due to the angles and possibly to shrinkage strains. Where the arm and section of rim are cast together, as seen in some well-known

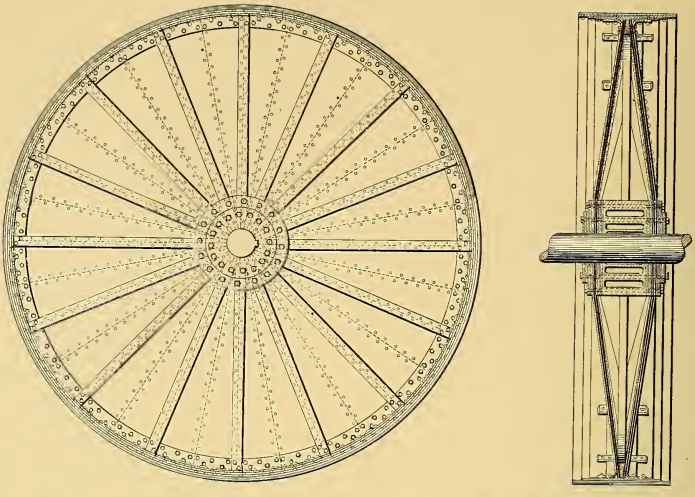


FIG. 2.—A 20-FOOT BUILT-UP STEEL BELT WHEEL IN THE POWER HOUSE OF THE ALBANY RAILWAY COMPANY, ALBANY, N. Y., U. S. A.

wheels, the junction of rim and spoke must necessarily be a weak point due to the shrinking of the iron away from this part of the casting.

When the shrinkage of iron is from one-eighth to one-twelfth of an inch to the foot, and some parts of a casting are chilled while others are yet molten, the tendency of the iron to shrink away from angles can readily be seen. The churning of iron in the mould as a remedy for this, as advanced by some writers, is of little importance, as the riser is always too small to remain molten long enough to be of much value in heavy castings. That shrinkage strains have much to do with fly-wheel accidents has been often proven.

That castings change their form after having the scale removed is well known too, and this, undoubtedly, has much to do with the wabble in many wheels. A wheel is jointed, bolted together and turned true on face and edges, and after it is taken apart and again erected in position on the shaft it is seldom found to run perfectly true, showing that there must be unequal strains on some of the connections due to the castings changing their form. The arms, if hollow, may be defective by the core rising in the mould, leaving one side heavy. If a green sand mould is used, uneven ramming may injure a casting.

The mixture of iron is also an important factor in fly-wheel construction. Very few large wheels are balanced, many builders depending on the different sections weighing the same as they are moulded from the same pattern. This, however, should not be relied upon, as castings from the same pattern are liable to vary greatly in weight. The well known formulas for computing the weight of fly-wheels are defective when used in all cases. In one case a wheel was replaced by another of one-half its rim weight and regulated the engine perfectly. In electric power stations weight is always an important factor as a means of securing steadiness in running.

It is not unusual to find a wheel of 50-inch face, with a hub bearing of only 24 inches. This may not be important when the hub is shrunk on the shaft and the wheel is new, but after a few years of service the wheel is certain to

begin to work on the shaft and when the main bearings are worn, a side thrust will develop which will throw an enormous side strain on a wheel. This it may not have been designed to withstand.

For small wheels cast-iron is probably the cheapest and best material, but the tendency to-day is toward larger and more powerful engines. That the wheel of the future will be of other material than cast-iron is, undoubtedly, the case, and on account of the great tensile strength and cheapness of steel, that material may be used.

The writer, in conjunction with Mr. Thomas E. Murray, consulting engineer of the Albany Railway at Albany, N. Y., U. S. A., has designed a 20-foot steel belt wheel which has been erected and is now running in the power house of the Albany Railway Company. This wheel, which was briefly referred to in the June number of this magazine, replaces a cast-iron wheel of the same diameter which burst last fall and caused much damage. The engine is one of a pair, and a second wheel is now under construction for the other engine. These engines are of the Cooper-Corliss type, 500 H.-P., tandem compound, 20″x36″x48″, and are belted to a 500 K. W. Edison multipolar generator. The speed is seventy-two revolutions per minute. The new wheel is built entirely of steel, except two cast-iron fillers, as shown in the illustrations on this page, and weighs complete about 27 tons. The steel used has a tensile strength of 60,000 pounds.

The hub consists of twenty ¾-inch steel plates and a cast-iron filler. The plates are put together in four sections and each section is held together by ¾-inch countersunk rivets. The sections are placed one against the inside and one on the outside of each disk and the cast-iron separator is between them. The illustrations show this arrangement plainly. The hub fits closely on the shaft and is held together by thirty-two steel bolts, which pass through from side to side.

The disks consist of thirty-two sectors of ¼-inch steel plate, riveted together in two layers with ¾-inch rivets, the joints broken and the outside joints covered by 5x¾-inch steel bars, thus making a continuous web. The two disks are set at an angle to each other on the principle of the bicycle wheel. This arrangement of the webs is one of the

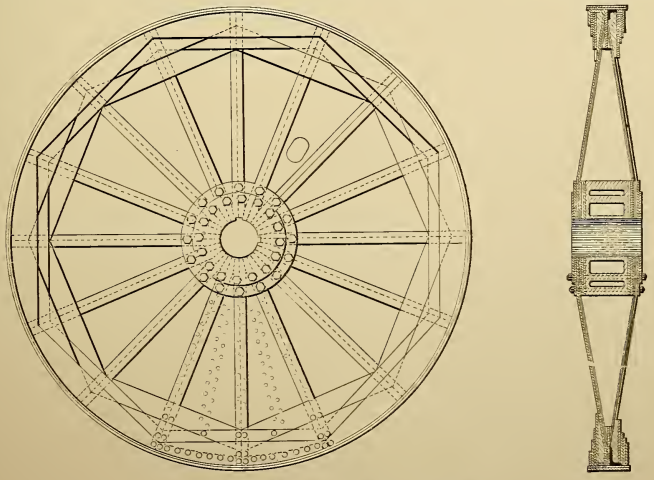


FIG. 3.—ANOTHER FORM OF BUILT-UP WHEEL.

most important features of the wheel as it prevents all vibration and side motion and makes the wheel run steady and true. At the rim again the disks are separated by a cast-iron filler ring.

The rim consists of four layers of steel plates and is connected to the disks by two lines of 6x6x½-inch angles, one on each side of the web. The outer layer of plates is 50 inches wide by ⅞-inch thick; the next is 50x⅝-inch; the next 40x⅝-inch, and the innermost is 32x½-inch. The inner plates, being narrower, give a better opportunity for riveting. The rim ends of the 5x¾-inch bars are bent over and two 1¼-inch rivets pass entirely through the rim and the ends of each bar, thus making a very strong connection. The weight of the rim is about 15 tons.

This wheel ran for some time without being turned, but that has since been done. While the nominal speed is but 72 revolutions, the wheel is guaranteed to run 250 revolutions, and it is calculated that it will run over 350 revolutions per minute safely and without bringing an excessive strain on any part and without danger of bursting.

The writer has also designed recently a 20-foot steel fly-wheel proper which is to weigh 100,000 pounds and which is intended for use on direct connected engines for electric power plants. The hub and web are essentially the same as in the wheel just described, except that instead of the twenty ¾-inch plates ten 1-inch plates are used, and the radial bars on the disks will be increased in size from 5″x¾″ to 6″x1″.

The rim consists of two outer plates 1-inch thick. A 1-inch plate 18 inches wide and sheared at the circumference of a circle 19 feet 8 inches in diameter is inserted between the disks and projects 6 inches beyond them. The angles between are filled with cast fillers, and the whole is securely fastened together. To this plate are riveted two rings of 6x6x½-inch angles, and to these angles the two outer plates are connected as shown on page 263. These plates are also connected to the 6″x1″ bars in the same manner as in the belt wheel. On each side of the web the angle is filled with an iron casting, and outside of this eight 1-inch plates, sheared into segment shape, are fastened, four on each side. These plates are of different sizes and the smallest are on the outside. The whole is held firmly together by bolts and rivets, making the whole rim virtually one solid piece. The wheel is moderate in cost and practically speaking, cannot burst from centrifugal force.

AUTOMATIC COAL WEIGHING MACHINES FOR POWER STATIONS.

By Francis H. Richards.

PROBABLY the progress made in no other art more accurately times the onward march of civilisation than the art, or business, of handling crude materials. With every reduction, for instance, in the cost of handling earth, more than a proportionate amount of earth-filling is made commercially profitable. The cost of handling ores and fuels, from the mines to the consumer, constitutes one of the larger items of their total cost at the place of use; and in whatever trade it may be, each handling of materials, every delay and incidental loss, is carried forward and ultimately appears in the charge against the consumer.

In power stations the problem of economical operation is not altogether the attainment simply of economy, but its maintenance as well. It is, indeed, hardly too much to say that the latter branch of the question is the more difficult of solution. In making a boiler

test, for example, not only is the environment usually modified, but the cost of the test itself is, generally speaking, entirely excluded. In regular work, however, all charges and conditions, and all changes of conditions, are represented in the result. We have, therefore, to ascertain not only what work may be done, but what is actually done day after day.

The late Hon. Eckley B. Coxe, who strongly advocated the substitution of a continuous record of actual performance for the prevailing system of occasional tests, once stated the matter very tersely, saying:—

"I am not so much interested in knowing what some expert may be able to do with my boilers, as to know what work my firemen are actually getting from them every day."

To know this, however, means the measuring of the intake and the output,—means accounting for the entire supply and production, so that the necessary comparisons may be made for formulating the result. In a power plant this, besides the accounting for cost of plant and attendance, involves the measurement of the materials used, of the fuel, ashes and water. This, again, involves an increase of labour and supervision, and, therefore, of cost, or the adoption of means whereby the measurements can be reliably and continuously made at a cost much less than the resulting gain. The automatic weighing machine supplies this requirement, automatically handling coal and water, much after the manner of an ordinary water meter, say, interposed in a water pipe, or a gas meter for that matter, giving a continuous and reliable record of what has passed through it.

In another way, too, may the automatic weighing machine serve a good purpose. Daniel Webster has been quoted for the way in which, in one of his speeches, he emphasised "the tremendous power of six per cent!" Certainly the investor of to-day looks sharply enough to the difference of one per cent. in the rate of interest chargeable against him. But does he look as closely to the other components of the "cost?" For instance, recent experiments indicate that the anthracite coal generally used for steam making will hold about four per cent. of water, without much dripping; and much of that coal is "watered" to this extent before delivery. If, now, the coal pile be replenished twice a year with wet coal, it is evident that the buyer pays the interest rate plus eight per cent. of the purchase price as the cost of the capital employed in "carrying" the fuel account.

Although the coal cannot, for obvious reasons, always be obtained dry, the drying may be readily effected in nearly all power stations before the coal reaches the bins by using heated air drawn from the upper part of the boiler rooms. Then, by weighing-in through an automatic weigher and reweighing in the same way, first to the bins, and next directly to the furnaces, all of the required facts are obtained. The first weighings, by showing the amounts taken in and delivered to the bins, indicate the evaporation, and a comparison of the records of the second and third readings will show, at any time, the amount held in storage in each bin, besides giving the amount chargeable to each set of boilers.

In order to fully realise in practice the advantages obtainable from the use of the automatic weigher as a record maker, the weigher must not only be efficient and reliable in itself, but it must, like other machines, be properly installed. Engineers, accustomed as they are to make ample provision for even the minor accessory devices of furnaces and boilers, should not give less consideration to the weighing machines through which the real performance of the plant is to be known—to the machinery, which, when once installed, becomes not merely an adjunctive apparatus, but a principal member of the system itself,—the one member, in fact, on which the management must rely for any accurate knowledge of the extent to which economy of operation is maintained.

While the space required by the weighers is not large, it must be prop-

erly located. In some cases this will necessitate slight modifications in conveyers, or, perhaps, in the plans of the building. In no case yet observed, however, would the necessary provisions, if made in the original plans, have materially enhanced the cost. A common error is to place the upper run of the main conveyer or make the outlets of the bins so low that the conduits to and from the weigher cannot be set above the angle of repose of the coal, notwithstanding the fact that there may be ample room above. Proper care in these respects will avoid using additional conveyers or other special devices, and greatly simplify the management of the apparatus.

The advance of the art of power production appears to have reached a point where the general adoption of the automatic weighing machine has become a necessity. The capacity of the plant, and its possible ratio of economy are determinable by the facilities already in use. But the changing relations of owners and operators, increase of direct and indirect competition, and the resulting changes in methods of management, clearly demand the development of the boiler test into a continuous self-recording operation.

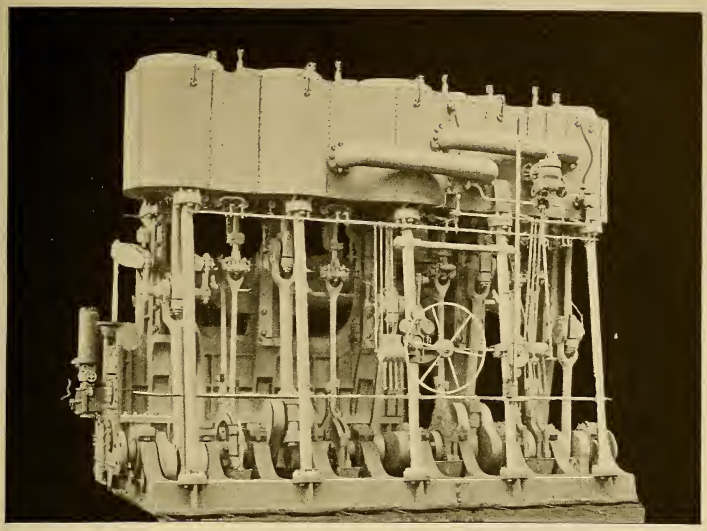
FIVE-CRANK MARINE ENGINES.

By Thomas Mudd.

THE new screw steamer *Inchmona*, belonging to Messrs. Hamilton Fraser & Co., of Liverpool, and built by Messrs. William Gray & Co., Limited, of West Hartlepool, England, is fitted with the first set of engines that have ever been built upon five cranks, and the question has been asked,—Why five cranks? The answer cannot be stated in a word; it is a question involving a compound answer. It touches all the reasons that caused three-crank engines to be adopted instead of two, and some things beyond that.

There are answers to the question which relate to the engine as a piece of mechanism, and there are some that relate to it as an apparatus for the economical use of steam; answers that have to do with the engine itself; answers that have to do with the boiler pressure provided outside of the engines; answers that relate to the effect of the motion of the engine upon the ship in which it is placed; and, lastly, there are answers that relate to the effect produced upon the motion of the propeller in the water. The movement to the greater number of cranks is believed to be in harmony with the general tendency of the age in several ways. The tendency is ever to higher and higher initial pressures; to larger sizes of vessels and higher speeds, and consequently more powerful engines; to further refinements, aiming at greater economy in the use of coal; and to the adoption of means tending to reduce vibration and increase comfort. When all the answers have been given that ought to be given to the question, "Why five cranks?"—it will be seen that this engine represents an endeavour to take a step ahead along all these lines.

The boiler pressure fixed upon in the case of the *Inchmona* was 255 pounds per square inch, and this pressure is provided in two cylindrical boilers of the ordinary multitubular type, which were tested by Lloyd's surveyors under hydraulic pressure to 510 pounds per square inch without showing the slightest sign of leakage. These are probably the first large cylindrical boilers that have been made for sea service at so high a pressure. For the utilisation of steam of from 250 pounds to 300 pounds per square inch initial pressure, it seems, in view of reduction of the range of tem-



THE FIRST SET OF ENGINES THAT HAVE EVER BEEN MADE UPON FIVE CRANKS. BUILT BY MESSRS. WILLIAM GRAY & CO., LTD., WEST HARTLEPOOL, ENGLAND. I. H. P., 1600.

perature in the individual cylinders, as desirable to adopt more than three stages of expansion as it was to adopt more than two stages when the pressure rose to 150 pounds per square inch; and although the engines of the *Inchmona* are not arranged for the adoption of five stages of expansion corresponding with the five cranks, they are arranged for four stages of expansion, which might have been adopted with four cranks.

In the writer's view, however, five cranks offer in many ways decided advantages over four cranks, and it would seem that if three cranks be abandoned, the step should be to the next odd number, five. With three cranks and with five cranks, set at equal angles, the impulses or initial stresses imparted by the pistons represent, in one revolution, a number equal to twice the number of cranks, and are yet delivered at exactly regular intervals of time throughout the revolution. With three cranks there are six equally distributed impulses in the revolution, three being upward and three downward, and with five cranks there are ten equally distributed impulses, five being upward and five downward. This is accomplished, in both cases, in conjunction with the condition that the cranks, being at equal angles, balance each other at all positions of the shaft, so that the shaft has no tendency to turn to any particular position due to unbalanced weight.

Three cranks will suffice even with four-stage expansion for small power, by placing one cylinder over another, but the plan is inconvenient for large powers. To move to five cranks is an advantageous step in a great number of ways relating to the mechanism. In the case of the *Inchmona* there are two low-pressure cylinders of equal diameter, and, therefore, not greatly larger than the No. 3 cylinder. This results in three important things:—

First, the centres of the engines, whilst being suitable for interchangeability of crank shafts throughout, are much closer together than they could have been with one large low-pressure

cylinder; in the second place, the reciprocating weights are very greatly reduced; and, in the third place, these reciprocating weights can all very easily be made equal to each other.

To have very light reciprocating parts; to have equal weights in the reciprocating parts on each crank pin; to have reversals of the up-and-down effects of these equal reciprocating weights following each other with only one-fourteenth to one-sixteenth part of a second between; all this means not only to have a very smooth-running engine, but to have an engine practically incapable of setting up vibration in a large ship. At 100 revolutions per minute these engines run with the greatest possible smoothness, and at that speed there are 1000 impulses per minute, or something like 16 per second, alternating between an upward and a downward impulse.

The division of the total power into five units, giving each crank pin only one-fifth of the total work, is a step in the right direction, reducing initial stresses on bearings, and the distribution of the power at five equal points of attachment around the crank circle results in an exceedingly uniform turning moment, which is so advantageous to the speed of the ship by the production of regular speed of propeller. In large engines the limit of power is determined, on the one hand, by the size the low-pressure cylinder can conveniently be cast, and, on the other, by the number of revolutions per minute at which it is safe to run with the actual weights of reciprocating parts necessary, assuming the boiler pressure to be constant.

There is nothing new in the adoption of two low-pressure cylinders, but when this is combined with four-stage expansion and five cranks, an opportunity is afforded for providing greatly increased power by securing such a true balance of parts as to make a higher speed of revolution easily attainable, other things being equal. With a given power of engine, the adoption of the five-crank principle involves very little increase in the length of engine room, whilst it affords greatly increased facility for the overhaul of working parts, owing to pistons and rods and bearings being so much smaller and lighter than they would otherwise have been.

The machinery of the *Inchmon t* comprises some other features that, whilst not altogether novel, are somewhat outside of the ordinary practice. The boilers are fitted with a battery of steam drying tubes, through which the steam passes on its way to the engines, and the cylinders are steam-jacketed in a more than ordinarily complete manner, with a view to trying to retain the working steam in a dry condition throughout its progress through the cylinders. The feed water, resulting from condensation, is taken up at a low temperature, due to the adoption of a high vacuum, and is passed first through feed heaters, heated by exhaust steam, and then through a further series of feed heaters, working at various pressures and temperatures, so that before it enters the boilers it is at a temperature of about 400 degrees Fahr.

The boilers are fitted with the induced draught system owned by Messrs. John Brown & Co., Limited, of Sheffield, by which a high rate of combustion per square foot of grate can be maintained, and also with their patent Serve tubes, which have the effect of increasing heating surface without increasing the size of boiler. These things combine to assist in keeping down the diameters of the boilers so as to bring the high pressure within the range of possibility without greatly increasing the number of boilers. In this system, also, the air for combustion is highly heated on its way to the furnaces.

Since the *Inchmona* is a cargo boat, and since the matter of paramount importance in a cargo boat's machinery is economy of fuel, the question that is of the greatest interest is that relating to the economy secured by the combination of parts and devices mentioned. Trials made when the vessel was light, off the port of Hartlepool, during a couple of days, resulted in the consumption of North Country coal at the rate of 1.07 pounds per indicated horse-

power per hour. Whether this will be improved upon with better quality of coal and with that improvement which always takes place in the running of new machinery, or whether it will fall off somewhat due to deposits on heating surfaces, etc., is yet to be proved by the experience of forthcoming voyages, but that the mechanism itself is successful as such, and that the five-crank engines run continuously in an unusually smooth and satisfactory manner, is already abundantly proved by the experience gained up to this time.

ELEVATOR CABLES.

By Charles Desmond.

THE duty exacted from some of the high speed elevators in tall city buildings is most trying to the apparatus. Were it not for the careful and frequent examination by trained and conscientious inspectors, accidents from falling elevators would be much more numerous than they are, especially as fully 55 per cent. of the defects are found in the cables.

Elevator cables are made of iron wire rope, consisting of a number of small wires, twisted into a strand, and several of these strands, the number varying according to the size of the rope, are laid around a central core which may be of tarred hemp. The wires making up one of the strands vary in number from 7 to 49. The ropes most commonly in use have 19 wires to the strand, because these are most pliable,—an essential quality in ropes which are used for hoisting and running over drums and small pulleys. These ropes are made of soft material, because it stands the wear and tear better, when running over small sheaves or pulleys, than that which is harder or contains a smaller number of wires to the strand. Only a soft and flexible wire will stand much bending.

The longest life of a cable, considered from the point of frequent bending, is estimated from the size of a sheave of which the diameter is 80 times that of a rope. Reducing the diameter decreases the life in an increasing ratio, so that with a sheave, the diameter of which is but 30 times that of the rope, the life of the latter will not be greater than 25 per cent. of the former amount. It will be seen that 80 diameters is taken as the maximum for practical purpose and 30 diameters as the minimum, for below this the bending strain on the rope becomes an uncertain factor.

There is another destructive element in the wear of the rope, caused by the strands and fibres rubbing against one another as the rope is bent during its passage over the pulleys. This difficulty does not amount to much with ropes having many wires to the strand, and especially when the strands are on a soft core which forms a cushion for them.

Wire rope is as pliable as new hemp rope of the same strength, and the greater the diameter of the sheaves, pulleys and drums, the longer the rope will last. A large number of small wires twisted together have such freedom of movement that there is little, if any, difference in the pliability between a rope made of iron wire and another of the same diameter made of hemp; but if the wires in the strands are of comparatively large size, they give the rope, as a whole, a stiffness that makes it impracticable for use where it is required to run over pulleys, although it answers well for standing rigging, for example.

The tensile strength of wire rope depends on so many different conditions that it would be impossible to state, with any degreee of accuracy, what

would be the strength of a wire rope of given diameter. Entering into this calculation would be the strength of material of which the wire consists, the number of wires in each strand, the number of strands and how the strands are laid, making such a combination that no certainty could be placed upon an estimated result, except from a test made of a sample.

The safe working load on elevator cables is usually taken at from one-seventh to one-fifth the breaking strain. Much depends on the abuse to which the cable will be submitted, for speed and vibration, "ramming," and other causes which may have a deleterious effect on the elevator cable while in use, all have an influence in determining the factor of safety that must be allowed.

Speed increases the wear of a cable more than load, because the load may be considered as a steady strain, while the speed at which it is run subjects it to more sudden bendings, and a greater number of them, within a given length of time. When judged from the effects produced, it leads one to believe that the effects of speed are much greater than would be considered as reasonable when the duty of the rope is considered; but the speed of the rope passing through and over the sheaves causes several movements of the rope, and among the wires, which have a tendency to abrade each particular wire.

Vibration that will produce an injurious effect on the rope by promoting the tendency to break the wires, may be produced by some slight inequalities in the gearing which will produce a vibratory motion. "Ramming," is the expressive term used to indicate the abuse to which elevator machinery is subjected by the elevator conductor who finds a certain sense of quiet enjoyment in starting the elevator with a bound that will take away the breath of the passengers and cause a sinking feeling at their stomachs as the elevator mounts upward, attaining a high rate of speed at the end of the first second after it starts; and, also, the same sudden change of rate of speed when the elevator stops at the floor level; usually it does not stop there, except after several rebounds and vibrations which cause more wear and tear on the rope than would follow several days' proper use. Again, when the elevator is descending, the same course is followed and before the passenger is aware of it, the elevator falls from beneath him and has gone down many feet before he has time to catch his breath.

The strain brought upon the elevator cable by such handling of the car is many times greater than the ropes were ever designed to withstand. When the car is started and made to attain a given speed at the end of a given time, the strain to which the cables are subjected will become a certain determinable number of foot-pounds; if the speed is doubled, or if the former speed is attained in half the given time, the number of foot-pounds will be four times the former amount, or as the square of the increase, and so on for any other changes in the rate of speed of starting or stopping. Understanding this,—which the ordinary elevator man does not,—it can be readily appreciated that even a factor of safety of 10 would be too small to insure the safety of the cables. The "ramming" elevator conductor should be disciplined, or educated, and it is only by ferreting him out and changing his methods, that elevator cables are capable of showing the length of life which most of them attain.

The wear of a cable due to friction and rubbing between the wires themselves and, also, between the wires and sheaves, is greatly lessened by keeping the ropes well lubricated with a suitable compound. This treatment tends also to prevent corrosion. Steel ropes are often preferable to those of iron wire because of the less wear which they show after a given amount of work. This is probably due to their smaller size for the same strength, there being less wear between the wires themselves and also, between the rope and sheaves. The diameter is also less; consequently the proportionate diameter of the sheaves over which they run will be greater. Steel ropes are fully 50 per cent. stronger than iron ones and a steel

rope ⅝-inch in diameter may contain as many as 300 wires.

In selecting a wire rope for small sheaves, one should be chosen which contains a large number of wires in each strand. These are the most pliable and are better suited for use on sheaves, or drums, of small diameter. A wire rope of a tough, pliant material is better than one formed of material of high tensile strength alone; particularly is this the case when the rope is subjected to sudden strains.

The ramming effect on elevators may, in some cases, be produced by causes other than those of the carelessness, or mischievousness of the elevator operator. It is noticed when air gets into the cylinder, or when a pocket of air is formed in any of the pipes in connection with the water supply to elevators. Air in the elevator cylinder will cause a jumping and plunging effect on the car. Under such circumstances it is a difficult matter, almost impossible, to stop the car at a given point without its vibrating up and down a number of times and covering a distance of a couple of feet, or more, at each vibration. The amplitude of vibration will depend on the volume of air in the cylinder or pipes, and the suddenness of the stop.

An elevator that gave strong indications of ramming whenever it was started or stopped quickly, presented a certain amount of mystery because it was impossible to find any air in the cylinder; yet every time it was started or stopped quickly it would make two or three jumps before it came to rest. The indications were that air was confined somewhere, but as it could not be found, the source of the trouble was thought to be in the valve and it was left in the same condition until an opportunity could be found to change it somewhat.

Before any change was made in this the question was raised that the trouble must be due to something else, because a number of other elevators with the same kind of valve,—the valves being made interchangeable,—were in constant use without showing any tendency to act in the manner indicated. An examination of the feed pipe from the supply tank,—using the compression system,—showed that the pipe rose 6 feet vertically from the tank, and then ran horizontally 25 feet with a 4-foot drop. The horizontal pipe had become an air trap that would occasionally deliver a supply of air to the horizontal cylinder of the elevator. The difficulty was overcome by inserting a simple air cock at the top of the pipe, allowing the confined air to escape each day.

Wire ropes are made in any length without splices or joints, except the joints in the single wires which are placed at different points in the rope, and these joints are made so as to be stronger than the wire itself and yet leave a smooth surface. The material from which wire ropes are made varies the tensile strength according to the quality of the wire; annealed iron wire has a tensile strength of 25 tons per square inch; charcoal wire, 34 tons; special, or extra plow steel wire, 150 tons. The working load for a ⅝-inch cable of charcoal iron for vertical lifting would be 1200 pounds; but if used for lifting on an incline the safe working load would be one ton under ordinary conditions.

Quick running ropes require a larger factor of safety than those used at moderate speed; it therefore becomes necessary, with high-speed passenger elevators, to use a factor of safety of 10. A lower factor of safety will be found quickly destructive to ropes operated at high speed.

Broken wires in a cable are due to the frequent bending, more than to the strain to which each individual wire has been subjected; but the broken wires, although dangerous to a certain degree on account of their liability to catch and further injure the rope, do not weaken the rope more than the percentage which the number of broken wires may bear to the number of wires in the cable; a slightly greater allowance than this is always made by reason of the effect which may have been produced by the greater strain to which the other wires have been submitted.

THE WORLD'S DESIRE FOR RAPID TRANSIT.

By George Ethelbert Walsh.

EVER since the birth of the human race the constant and persistent aim of man has been the annihilation of time and space by mechanical means. In his rude and ignorant way primitive man worked out the problem of speed to the approximate satisfaction of his times and needs, and contributed by his effort and experience an inheritance of knowledge that has constantly swelled and expanded in volume up to the present day. Under slightly changed conditions each generation has studied the question, adding its mite to the storehouse of positive knowledge, and never resting satisfied with the achievements of its predecessors.

The savage's conception of speed must have been relatively higher than that with which we are at first inclined to credit him, although his practical accomplishments in this line were extremely limited. The swift footed beasts of the field excited his envy and admiration, and the rapid-flying birds of the air must have awed and inspired him. The speed of the former he soon made his own by conquering and taming the fleetest-footed animals of the country, but the speed of the latter has remained, even down to the present, his ideal of the maximum. The flight of the bird is the study of modern science, both as regards speed and conservation of energy.

Mechanical devices for accelerating the speed of travel appear early in the history of every tribe and nation, and with few exceptions more thought and energy have been continuously expended upon their improvement than upon any similar class of subjects. The present era of discovery and invention in the field of rapid transit belittles the achievements of all preceding periods, but the trees which yield so abundantly of fruit to-day have their roots in ages long since past, and traces of their gradual development are discernible in various ways. To assume that all of the credit of modern inventions belongs to us is to deny the existence of that continuous stream of endeavour that marks the history of mankind.

The secret of the persistent effort of man to annihilate space is found either in necessity or pleasure. In his boundless forest and limitless desert, the savage found himself in need of food and protection, and the surest way to obtain both of these was to increase his speed of travel. His provisions must be gathered from far and wide, and his safety from wild beasts and human enemies must be secured through superior strength or cunning. In the struggle for existence Nature provided primitive man with apparently the poorest equipment for self-protection against all other animals; but in the gradual triumph of mind over matter a power was revealed that he little understood. The inventive genius that could make the horse and camel contribute to his needs and pleasures, or could fashion the canoe and boat to carry him across rivers and streams, or make the primitive sled and snow-shoes a means of transportation across snow and ice, was the same that to-day harnesses a Niagara to turn the wheels of a thousand factories, or stores the electric fluid of the earth and air to make

transportation cheap, rapid and clean. The maximum of rapid transit of one generation has generally been the minimum of the next, and the progress toward a higher conception of speed within the bounds of safety has been marked in each period by a series of slow, toilsome experiments. The efforts made to-day to solve the aerial problem, or the question of higher railroad speed, are merely the repetition of constant endeavours of men in past ages to accomplish similar results. Before machinery was invented for transportation purposes, the horse, the camel, and the deer were reared carefully, and selected with special reference to their strength and fleetness for rapid transit purposes. Besides training the beasts of the field and forest to this end, the Indians of the American continent developed their own fleetness of foot, so that they could contend in a race with the wild horse. In a long run the Indian could tire out the four-footed messenger, and even in short races he would give a good account of himself. On snow-shoes and toboggan he became an adept, and developed the art of traveling by these appliances to the very pinnacle of perfection. No civilised white man could overtake him in a race across the snow-clad mountains or prairies, and even the wild beasts became an easy prey to his rapid flight. On the water he was equally skillful in handling the canoe.

In their particular field of endeavour the uncivilised inhabitants of the globe accomplished results that cannot be despised by lovers of rapid traveling to-day. The Arabian horse was bred and trained to excel all others, and his speed has become proverbial, "likened unto the wind." Carefully kept and corrected records of horse racing and horse trotting are preserved to-day so that we know the highest speed attained, but of the many celebrated horse races on the Arabian deserts we have no printed account. The famous Kochlami breed of Arabian steeds, however, have never been excelled in beauty, intelligence, powers of endurance, or speed. Accounts of their wonderful performances, colored by the picturesque exaggeration of the children of the desert, read like fairy tales; but sufficient authentic history about the powers of these animals can be gathered to assure us that they were nearly as fleet, if not fleeter, than our present-day race horses. The highest record for horse running stands at one minute and thirty-five and one-half seconds, run by Salvator, in the United States, on August 28, 1890. This maximum was obtained only under exceptional conditions, good weather, splendid track, fine riding, and perfect grooming and care. On the wild desert the race would be different, and the steeds of long ago might prove themselves under similar conditions superior to the product of modern high breeding and selection.

In the same manner the wild American Indian horses of fifty years ago could tire out and distance the best imported horses from Europe, provided the race was across the rough country so familiar to the Indian and his steed. The development of the animal's speed had been carried on systematically by the Indians, until, mounted on one of these broncos, a warrior could run down almost any wild beast of the mountains or prairies. The highest degree of horse racing for such rough country was reached by the savages a century ago.

Horse trotting and horse pacing are artificial accomplishments that have been fostered and encouraged in civilised lands as a means of affording pleasure to the riders, and no comparison is required to show that speed has been greatly increased in this line. The aborigines of any country care less about the beauty and grace of their horses in traveling than about their speed, and it is only natural that they developed the running horse, and despised the pacer and trotter. The highest speed yet attained in trotting was made by Alix at Galesburg, Ill., U. S. A., when a mile was covered in two minutes and three and three-quarter seconds, and the best pacing record was made at Terre Haute, Ind., U. S. A., by Robert J. in two minutes and

two and a half seconds. Speed alone being considered by the Indian or Arab, these records for fast time would be considered low.

When we turn to other methods of attaining high speed, we find that the early records have not been much improved upon in modern times, when the fever for rapid transit in all its forms seems to have permeated our whole civilisation. Professional walking, except for long distances, was not considered sufficiently fast to warrant its cultivation by primitive races, but running was an accomplishment that appealed with great force to all classes. Necessity compelled the hunter and warrior to be a fleet and powerful runner, and the ambition to excel in the races invariably stimulated others to increase their speed by constant practice. The early Greeks brought the art of running to its highest perfection, and had records been preserved then with the same care as to-day the modern amateur or professional runner would probably have something to envy. The American Indians were almost as fleet of foot as their four-footed friends, and the present world's record of four minutes and twelve and three-quarter seconds must have been equaled by many of the young bucks of the savage tribes.

The highest canoe record for a mile is six minutes and forty seconds, made in 1894, at the fifteenth annual meet of the American Canoe Association, and the quickest time a mile has been covered by a man rowing in a boat was on the Savannah river, Fla., U. S. A., in 1892, when the time was five minutes and one second. The conditions in both instances were all that a professional or amateur could desire, and everything in the way of mechanical skill had been done to increase the speed of the boats. Yet it is more than doubtful if these records were the highest ever made.

We have it on good authority of travelers and early pioneers that the Esquimaux in their skeleton, skin-covered boats, and the American Indians of the Hudson Bay territory in their rudely fashioned canoes, could cover distances much faster than any white man, and that their speed approached almost to the marvelous. The same is true of their snow-shoe traveling. The Alaskan Indian to-day holds the record for rapid traveling on snow-shoes over a wild, rugged, broken country. The Esquimaux, with his sled harnessed to a pair of fine reindeer, holds the record for fast traveling by vehicle across snow or ice, with the possible exception of modern ice-boats. The ice-boat of the Hudson river has attained a speed of a mile a minute, but the reindeer of the Laplanders travel, on an average, ten and twelve miles an hour over the frozen snow, dragging a sled and its owner behind. When forced to his highest speed the reindeer can travel a mile easily in two minutes with his harness and sled attached, while, when freed from these fetters, it is reported that a mile a minute has been covered by these sturdy inhabitants of the cold zone. For cross country riding, when snow covers the ground, the Laplanders, despite their uncivilised life and habits, hold the record, and can put to shame the highest speed of modern inventions.

The advent of machinery, and the discovery of invisible forces to move it, brought in a new era of rapid transit. Up to this time, however, the speed attained by our ancestors in traveling over the land and water had progressed gradually and surely until the maximum through the physical effort of man or beast was reached. The only way to increase their rate of traveling from place to place was to harness the birds of the air, or to resort to mechanical methods never yet dreamed of. But to do this some powerful motive force had to be discovered, and in the absence of it they could but look in awe and admiration at the birds of the air in their daily flight. How slow and insignificant was the highest speed of their horses or reindeer compared with the small swallow, the delicate humming bird, or the showy eagle of the mountain peaks! In watching the graceful and speedy flight of these, what won-

der that early man believed that there was still a higher maximum of speed to be obtained through the physical exertion of nerve and muscle!

Even in these times this belief is not entirely dissipated by repeated failures and fruitless experiments, but the question is better understood. While the flight of the bird represents the highest and most perfect type of animal locomotion, its superiority is also partly due to the medium in which it moves. The physical strength of man or beast could never be developed to the degree of perfection which would enable him to compete on the land with the birds of the air. So far even man's mechanical contrivances, with the aid of steam and electricity as motive powers, have been unable to equal the flight of many of the birds.

The wildest theory places the speed of the future bicycle railroad trains, propelled by electricity on elevated railroads, at considerable less than two hundred miles an hour; but this is the extraordinary velocity that the frigate bird is supposed to attain at times. The relative speed of birds is very uncertainly understood and verified, and records are only approximately true. In the study of the speed of birds it is impossible to note more than the amount of time required to cover several miles in succession. The pigeon, in flying from one dove-cote to another, has been known to make a mile in a minute and nine seconds in a two-hundred-mile race, and another averaged a mile every minute and fifteen and a half seconds in a four-hundred-mile race. In such experiments one is at a stand which to admire the most,—the relative speed of the birds, or the tremendous powers of endurance.

It is a well-known fact that the falcon can overtake the pigeon in a race, and its speed is estimated at nearly twice that of the ordinary carrier pigeon. Well-trained falcons have covered seventy-four miles in one hour, and hawks are said to make one hundred and fifty miles in the same length of time. The crow is a slower bird than any of these, but even its clumsy flight averages twenty-five miles an hour. The frigate bird, however, excels even the hawk or falcon, both for its speed and its long-sustained flights. In the tropics it can be seen hovering for lengthened periods in midair without a movement of the wings perceptible; but its sudden flight downward toward the water is like the flash of lightning. While the total length of the frigate bird is only three feet, the expanse of wings is from six to eight feet. It is frequently found long distances from land, but it never seems to tire of flight. Its speed has been estimated at two hundred miles an hour, or a mile in eighteen seconds. The Kestrel or sparrow hawk is said to cover one hundred and fifty miles in an hour.

How this tremendous speed compares with that induced by man's contrivance, even in this marvelous age of rapid transit, can be seen by examining the speed of a gun projectile. Some of the high-power guns of to-day expel their projectiles at a speed of 3300 feet per second at the muzzle, or about one and six-tenths of a second per mile; but as the speed constantly diminishes after it leaves the muzzle, the speed cannot be estimated much higher than four or five seconds per mile over a course of five miles or more. The cannon-ball and the rifle-ball represent the highest speed attained by man through his personal efforts, but these are useless for the purposes of transportation.

The acme of rapid traveling was reached in 1893, when the Empire State express, on the New York Central railroad, in the United States, made a mile in thirty-two seconds, near Crittenden, N. Y. This speed was at the rate of 112½ miles an hour, the highest speed developed by any steam or electric conveyance in the world. This record is for only a short distance, and does not represent the average between any two points, but simply the highest rate that has ever yet been forced from any mechanical contrivance of man. The highest speed of a train hauled by electric means was made on the Baltimore and Ohio railroad, in the United

States, at the Baltimore tunnel, in 1895, when a mile was covered in fifty-nine seconds. As electricity for moving trains is yet in the early stages, this slowness, compared with steam railroad speed, is not so significant as it may appear at first. Certainly the marvels of electrical rapid transit predicted for the near future would off-set any such little difference in the present relative speed between it and steam.

A corporation has already been projected at Washington, and the American Congress has been petitioned to grant a charter for the right of way for an elevated road between that city and New York to carry passengers and mail at the rate of 120 miles an hour. The trains are to be lighter than the ordinary ones run on steam roads, and they are to travel on a road built above the ground, with one line of wheels below, and auxiliary ones on the sides to steady the motion of the cars. As several similar "bicycle" railroads have been proposed and experimented with in the past, it may be surmised that it is easier to build such a line on paper than on the ground. When such a rate of speed can be obtained, and steadily maintained over a course of several hundred miles, we shall have rapid transit indeed. But until then, we must look to the flight of birds for real rapid transit even as our ancestors did thousands of years ago.

The flying-machine has been steadily unfolding its wings before the public during the past decade, but, except in theory, we seem little nearer the solution of this problem than before. The air certainly offers less resistance to rapid transit than the water, and much less friction than the iron rails of a tramway; but unfortunately birds still guard their secret of balancing themselves calmly in the air, and of utilising every current of wind for motive power. Should aerial navigation ever become an established fact, we might find ourselves, in time, traveling at a speed of two hundred miles an hour. But, meanwhile, flying-machine inventors will be satisfied to travel at the rate of twenty miles an hour through the air. Speed at present is no desideratum with them; they merely seek the power to float and glide along safely.

With the introduction of steam and electricity the speed of boats was increased so greatly that the records of primitive man's canoe and sail-boat are hardly worthy of consideration. Rowing and canoeing had been developed to their highest point, and even the powers of the sail were pretty fully tested and understood, before the era of steam. But ocean steamers to-day make all records of speed on the ocean ridiculous by comparison. The highest speed of the steamship *Lucania* is a mile in two minutes and thirteen and four-fifth seconds. Even this is not by any means the highest speed obtained by modern inventors. Torpedo boats make much better time, and average a speed that would leave the *Lucania* far behind in a race. The Russian torpedo boat *Sokol* holds the record for fast travel on the water, having made a mile in one minute and forty-five seconds.

The bicycle, tandem and motor wheels have all come in for their share of record-breaking, and predictions are freely made that these modern inventions for traveling will make rapid transit higher on the land than ever before. But so far the bicycle has only covered a mile in two minutes and two and two-fifths of a second standing start, and one minute and fifty-two and three-fifths seconds with a flying start, while the bicycle quadruplet has made a mile in one minute and forty-six and three-quarters seconds with a flying start. The motor bicycle and the horseless carriages have just entered the field, and it is hardly fair to give their highest records for comparison. In the international race of 1895, between Paris and Bordeaux, a horseless carriage averaged a mile in four minutes. In a short race, under more favourable conditions, this speed could probably be doubled, while further improvements may make this vehicle a formidabe rival of steam and electric cars.

Record-breaking in fast travel thus goes on and each year man directs his energy toward still further progress.

SAND BLAST APPARATUS FOR CLEANING CASTINGS.

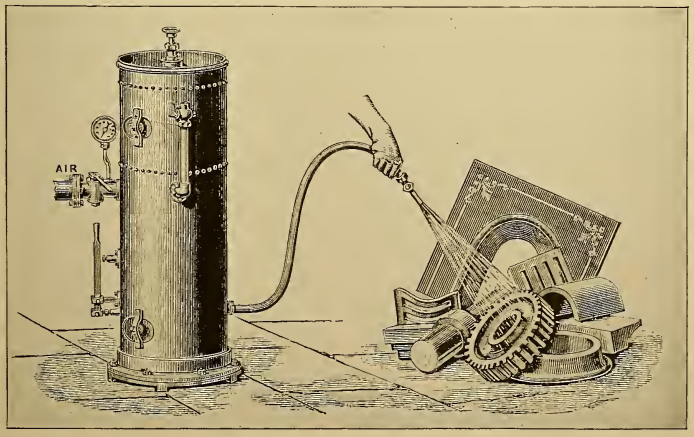
F. C. Brooksbank.

The following data concerning the use of the sand blast process, appeared first in the shape of a paper, recently read by Mr. Brooksbank before the Foundrymen's Association at Philadelphia. To this, however, it has been thought well to add several illustrations of representative sand blast machines which tell their own story.—THE EDITOR.

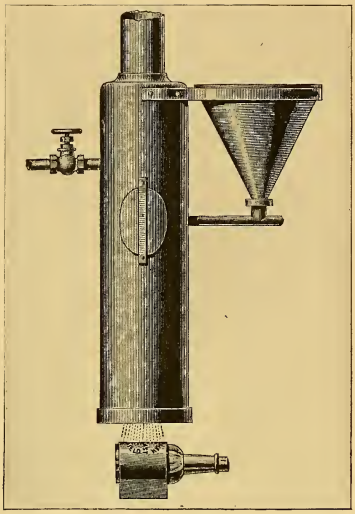
THE invention of the sand blast process by Gen. B. C. Tilghman of Philadelphia, Pa., in the year 1870, marked the introduction of an entirely new process into the arts. In the twenty-five years that have elapsed since that time, the process has been in constant use for an increasing number of purposes, and seems destined to retain a permanent place of its own in manufacturing operations.

The method, stated shortly, consists of projecting a stream of sand or other abrasive powder, usually dry, but sometimes mixed with water, with more or less force and velocity to strike and pulverise the surfaces of glass, stone, metal and other materials upon which it is directed.

It has been frequently pointed out that in this invention Mr. Tilghman has really borrowed or adopted from Nature herself, inasmuch as he has intensified and put to use a natural force, of which the effects are always apparent under favouring conditions; that is to say, wherever we find large deposits of loose sand, exposed to prevalent winds, by which it is caught up and blown against any hard substance, such, for example, as the glass in a window, the surface, with time, is sensibly roughened and



CLEANING CASTINGS WITH A SAND BLAST APPARATUS. MADE BY THE TILGHMAN PATENT SAND BLAST CO., LTD., SHEFFIELD, ENGLAND. MESSRS. WARD & NASH, AGENTS, BOSTON, MASS., U. S. A.



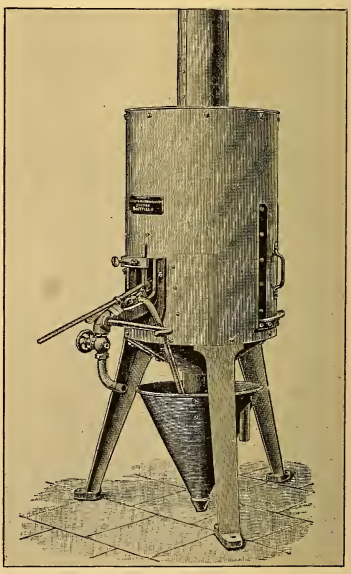
A TILGHMAN SAND BLAST BOTTLE MARKER.

sometimes scored in a manner quite distinct from ordinary weathering.

The abrasives used in the process include ordinary inland siliceous sand, sharp builders' sand, powdered glass, emery from fine to coarse, chilled iron sand and steel shot ; and the stream of the powders is forcibly projected through variously formed nozzles by means of steam, by currents induced by exhaust air, by blasts of air, and latterly and more conveniently by compressed air. Sand, from its plenteousness and general suitability, is mostly employed.

The action of the sand blast is not cutting, not grinding, not abrading in any of the usual meaning of these terms. It is a true pulverisation by the successive impact of the grains of flying sand. The sand acts much in the same manner, but on an infinitely reduced scale, as artillery projectiles in breaching a masonry wall, each independently of all the rest. In this action it differs from anything that has preceded it and it still stands alone. How the sand is given velocity or how the work is presented to the blast, are matters of indifference when examining the theory of the process. As the total action of the blast is but the summation of the action of the individual grains, the action of the individual grain is to be considered. If the single grain of the flying sand has no effect when it strikes the work, then no other grains will have any, and the sand blast will be without effect, no matter how long continued. If, however, the single grain of sand has any effect upon the object struck, then the blast will wear it away often at an extraordinary speed, as the number of grains propelled against it is very large, often as many as 5,000,000 per minute.

Grains of sand have numerous angles, and the action of these grains, as also that of the other abrasives mentioned, upon the surfaces of glass, stone or metal, is due to the circumstance that every individual grain in the infinite number in the incessant stream, urged violently forward, has all its energy instantly arrested, transferred and concentrated upon its point in impact,



A SAND BLAST FILE SHARPENING MACHINE.

where it produces a minute pit or depression; and, as every grain in the shower acts alike, the abrasion resulting from the whole is perfectly uniform in depth and texture or roughness. The single question, therefore, to be considered is, does the stress at the point of impact between the grain of flying sand and the object struck rise high enough to overcome the strength of the latter?

Three factors determine this:—1. The energy in the flying grain; this belongs entirely to the strength of the blast. 2. The area upon which this energy is expended; this belongs principally to the object struck, although the shape and size of the sand of the blast have some effect upon it; and, 3, the strength of the object struck, which, of course, belongs entirely to it.

The energy contained in a single flying grain of sand is very small, even when traveling at a very considerable velocity, but it is the exceedingly small area upon which this is expended that makes any cutting by it possible. As an illustration of the above points, take, for instance, the case of a sand blast using sand of an average of 1-50 inch in diameter and propelled by steam of 50 pounds to the square inch, cutting granite. Such a blast, under these circumstances, will cut granite rapidly. Why? Determining the above factors, first, such sand grains will weigh on an average about 0.005 grain and will be moving at the point of impact with the stone about 400 feet per second, and will, therefore, contain about 0.00176 foot-pound of energy. This is certainly a very small amount, but next, take the area upon which it is expended.

The area of first impact can only be estimated from the following considerations:—If a piece of smooth, hard substance is scratched with the edge of a crystal, as, for instance, in ruling diffraction gratings in which lines are readily ruled at the rate of 12,000 to the inch, and we examine them under the microscope they are seen to be narrow in comparison to the space separating them, being themselves probably not more than 0.00002 inch broad, and it is upon a rectangle with a length of side equal to the breadth of one of these lines that the first impact occurs. This is 0.000,000,000,4 square inch. And the above determined 0.00176 foot-pound of energy, distributed upon this area, is at the rate of 440,000 foot-pounds per square inch.

Now, the strongest granite can stand a quiet crushing strain of only about 1200 tons per square foot, or at the rate of about 16,600 pounds to the square inch. The contest between the stress developed at the point of impact and the resistance of the object struck is in this case overwhelmingly in favour of the stress developed. The result is that the granite under the point of the first impact is crushed and crumbled to dust, letting the grain of sand progress, expend its energy and increase the area of contact until the pressure there falls below the crushing strength of the granite; then the action of that grain is over and it rebounds from the stone. The striking edge or point of the grain of sand is also crushed and contributes to increasing the area of contact between it and the granite.

The effect of the above sand blast when striking a piece of wrought iron in place of the granite will be that the iron, instead of being pulverised like the granite, is only indented. The result is that no metal is removed, but a small indentation is produced. Other grains, striking in the immediate vicinity of this indentation, simply shove the metal back into it again and obliterate the effect of the first grain. Thus no effect is produced, but the surface is simply roughened by the indentations of the sand grains. This is the normal effect of the blast upon all metals. If they are exposed for a long time to the action of the sand, as in a sand blast machine, metals wear away, because the surface metal is exhausted by the constant bending, so that it at last breaks. If the blast is directed upon a piece of soft rubber, the same action as in the case of the metal takes place, but in this case the elasticity of the rubber is such as to enable it to resume its origi-

nal shape after the force of the impact has been expended in deforming it, and there is no residual effect whatever upon the rubber, the grain of sand rebounding with almost its original velocity. These three actions and the combinations of them explain all the different effects of the sand blast in cutting and refusing to cut various substances.

In surface obscuring or ornamenting, such as in glass work, for which the sand blast has been more used than for all other purposes combined, the problem is entirely different. The effect wanted is to break the continuity of the surface struck, and this once obtained, any further force in the blow of the sand is wasted, and an exceedingly great number of light blows is what is desired. Therefore a very fine sand is used and a large quantity thrown in proportion to the propelling jet, which gives a moderate velocity. So important is this adaptation of the size of sand to the work that if two exactly similar machines are taken, one using fine and the other coarse sand, and both using the same pressure of either air or steam to drive the sand and the same size jet, the machine using fine sand will obscure three times the work that the machine using coarse sand will do. But in cutting or perforating glass or stone, the machine using coarse sand will do three times the work of the machine using fine sand. In one case the blows are too few to break up much surface, and in the other case they are too light to do much cutting. Thus, by use of sand unsuited to the work, the efficiency of a good machine can be reduced over 60 per cent.

The earliest form of apparatus perfected was the high-pressure steam jet described in the patent of 1870. In this a small jet of high-pressure steam of an annular shape escapes into a larger tube and draws along with it a current of air through a central tube, which is surrounded by the annular steam jet. This entrained current of air carries with it a large portion of sand and becomes mixed with escaping steam and is thrown directly against the work at a high velocity. The nozzle tube is made of hard white iron and so constructed as to be cheaply and easily replaceable. This form of jet for hard, heavy cutting is as efficient in output of work in proportion to power used as anything that has been constructed since. Its other disadvantages, however, have caused it to be abandoned in favour of other devices of more modern construction.

Among these were chiefly the wetting of the sand each time it was used; clogging of the sand feed pipe if the drying was imperfectly done; enveloping the work in a cloud of steam so that the progress of the work could not be followed by the operator; cracking glass articles by the sudden and unequal application of heat to them, and rusting all articles of iron or steel, subsequent to the cleaning, by wetting them with hot water from the condensed steam. The use of compressed air avoids all these disadvantages. In spite of all these, however, this system was used for a long time to a considerable extent in the stone trade, among other things doing the marking of over 100 000 tombstones in the national cemeteries, cutting down the whole face of the stone and leaving the inscription in raised letters, about one-quarter inch high.

For cleaning metals, however, these disadvantages have totally prevented the use of the steam jet. Compressed air was tried in the same form of jet. Although it did good work, it did not succeed practically or commercially on account of the great expense of providing a sufficient supply of compressed air at the pressures required. The small amount of work that a jet of compressed air, used in one of these old induction feed steam jets would do was remarkable, and most discouraging in comparison with what a jet of steam would do under the same pressure. The whole class of induction feed jets would not work reliably at the lower and more economical air pressures. They, however, would work well, cost not considered, and completely obviated the faults just referred to of the steam jet.

In a recently designed machine these

points have been retained and there has been secured also the full efficiency of the blast, due to the pressure at which it is used, unreduced by the admixture of any dead air carrying the sand with it, at just the place where the maximum velocity is desired. This machine uses air at all pressures, but those about 10 pounds to the square inch are found to be the most satisfactory. By immersing the whole sand supply in an atmosphere of air at the above pressure, contained in a tight reservoir, the advantages of a purely gravity feed are obtained, uncomplicated by any questions of difference of pressure inside of the jet tubes and without.

Then, by the use of a flexible tube of considerable diameter, the sand and air, in a mixed current, are carried to a point where they are to be used. Here the flexible tube is terminated by a hard chilled iron cone, terminating in a tube of small diameter. In traversing this latter portion of its course, the mixed current of sand and air increases its velocity inversely as the square of the diameter of the tube, and is finally discharged from the end of the blast nozzle at the full velocity due to the pressure behind it. An air lock arrangement for transferring new supplies of sand into the sand reservoir, while still under pressure, and valves for operating and graduating the air and sand supply, with a suitable compressor for furnishing the supply of compressed air, complete the arrangement. This machine is comparatively new in the United States, but has been used to a considerable extent in England and on the continent for cleaning scale from sheet metal and castings and forgings. The machines are built in different sizes, and, of course, their output of work depends strictly upon the amount of compressed air that they use per minute. A machine using 60 cubic feet of air per minute requires 3 indicated horse-power to run the compressor, which furnishes this amount of air compressed at a pressure of 10 pounds to the square inch.

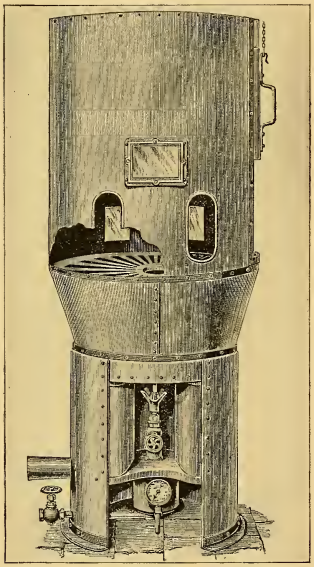
At this volume and pressure, the work accomplished on ordinary rolled steel plates is 1 square foot of scale removed per minute. Iron plate usually has thicker scale and requires slightly longer time. Forgings and castings differ so much in the nature of their scale, both from kind and heat of iron, kind of moulding sand and several other particulars, that it is impossible to give any general rate which will be sure to suit more than the individual case which is considered. Trial is the only safe criterion.

The recent improvements and inventions of Mr. Mathewson, manager of the Tilghman Sand Blast Company, at Sheffield, England, have given a new impetus to the use of sand blast for a great variety of purposes. In metal it is used for the removal of the hard scale, so destructive to cutting tools, from castings and forgings. Among the applications are the removal of the scale from sheet iron and steel prior to enameling, galvanising, nickeling, tinning, etc.; the cleaning of tubes and brazed joints, largely used in bicycle work; sharpening the teeth of files; for granulating or frosting electroplate, gilding metal, gold and silversmiths' work and jewelry; the reduction to clean metal surfaces of larger work, ranging from steel forgings of safes to armour plates; on stone, slate and granite, for incised carving and inscriptions in intaglio or relief; for cleaning off the grime from stone, granite and brick buildings, and, in contrast to this last, for the most delicate drawing for lithography.

Among other purposes it is employed for removing fur and deposits in tubes and tanks; for cleaning off accumulations of paint and dirt within iron ships; for roughening the surfaces of metal rollers; for decorating coat and other buttons; for granulating glass to give it a key for ornamental painting by hand; for piercing the apertures in glass ventilators; for marking cakes of glue and cement; for marking pottery, and in the manufacture of ornamental tiles; for smooth-facing bricks to receive white glass or enamel; for refacing grindstones, emery and corundum wheels; for granulating celluloid films for photography,

and on wood to bring out the grain in relief.

Another recent improvement in connection with the use of sand blast is the application of it in connection with tumbling barrels. These barrels run very slowly (two or three revolutions per minute); consequently there is little risk of breaking fragile castings; neither are the edges of them worn off and destroyed, as in the case of ordinary rattling at high speed. The castings are not cleaned by tumbling, but by sand blast inserted at one or both ends of the barrel. The usual time consumed in cleaning a charge of this barrel



APPARATUS FOR CLEANING AND FROSTING ARTICLES OF METAL OR GLASS.

The articles to be cleaned are placed upon a grating inside of the chamber. The operator, standing with his eyes at the window, and his arms through the oval-shaped openings in the chamber, grasps a piece and holds it in the blast a few inches above the opening in the grating. The article is then moved about so as to bring all parts under the action of the sand.

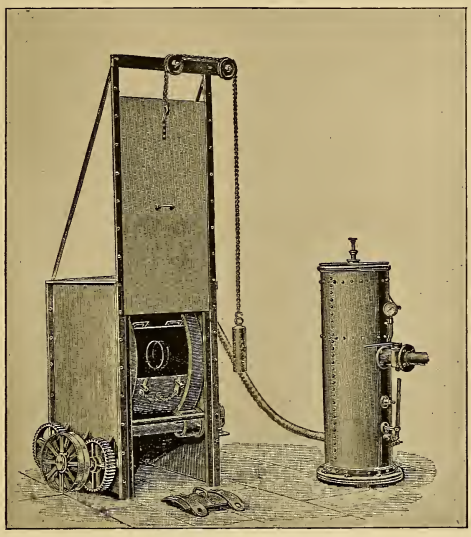
is from 20 to 30 minutes. The latest design of this machine is arranged in an elevation directly over the sand blast apparatus, which has two flexible tubes and nozzles. These are inserted into each end of the barrel, which is enclosed and provided with an exhaust fan to carry off the dust. The barrel is perforated with small holes, through which the sand falls through a hopper and directly back into the sand blast apparatus, thus making it almost entirely automatic.

There is another application of the sand blast which is just beginning to attract the attention that it deserves. This is in the preparation of metal work of all kinds for painting as a protection against corrosion of all kinds, principally, of course, in protecting iron work against the weather. For this purpose the one necessary condition is to get a close contact between the metallic iron and the oil of the paint. If this is secured, the paint will last and stick in a manner entirely unknown in the present ordinary commercial painting of iron structures. If this absolute contact of paint and metal is not secured and the thinnest coat of oxide, either rust or scale, intervenes, the painting is in a great measure useless. The paint, not reaching the iron, cannot stick to it; it can only stick to the coat of oxide which it can reach, and as a result when the coat of oxide loses its hold on the iron and drops, the paint comes with it.

The difference between what can and should be done in the way of protection of iron by paint and what usually is done is shown in the case of ship plates, when, as is sometimes found, the numbers and marks painted on the plates in the rolling mill when the sheets are perfectly clean, just from the rolls, are found of the full original thickness of the plates, while the rest, painted in the ordinary way, is so much corroded as to render it necessary to replace the plate. This degree of protection is what should always be obtained and which can be best obtained if iron is thoroughly cleaned by sand blast immediately before it is painted. The author will venture to predict that it will not be a long time before the specifications of structural iron work to be protected by paint will usually call for a

thorough sand blast cleaning immediately before painting.

Another use for which a large demand for sand blast work may be predicted is in boiler making. At present the sheets, covered with oxide, are placed together and riveted up. The blows of the riveting thoroughly pulverise the scale on the plates where they lap on each rivet, leaving a thin layer of powdered scale between the plates, through the interstices of which steam and water under pressure will find their way. To prevent this, the excessive caulking now used is necessary. If the sheets were clean, metal to metal, without foreign substances between them at the joint, much of the present caulking would be unnecessary. This would leave the full strength of the rivets and plates to withstand the internal pressure instead of having a large portion of their strength taken up in withstanding the initial strains produced by caulking. The ordinary method of attempting to produce a clean metallic surface on castings, forgings, etc., for these and other purposes is by pickling. This process, apart from its numerous well-known disadvantages, which make all who have anything to do with it wish to replace it with some other process, has a serious effect upon the internal structure of the iron, as the following reports of experimental results will show.



A SAND BLAST TUMBLING BARREL.

The castings are placed in a slowly rotating cylinder, supported at its circumference on rollers. The blast is directed through one or both of the ends of the cylinder against the articles placed in it. The slow rotary movement given to the cylinder causes the castings to tumble over one another, thus continually bringing new faces under the action of the blast.

The effect of pickling and rusting on the strength of iron and steel has been shown by A. Ledebur of Berlin. Rails, joists and bars were subjected to various conditions :—1. In the condition as delivered. 2. After exposure for purpose of rusting. 3. Galvanised and tested at once. 4. Galvanised and exposed for a a time. 5. Pickled in acid and immediately tested. 6. Pickled and kept

for a time in a dry place. The pickling was done with sulphuric acid diluted with water in the proportion of 1 to 100. The samples were tested for transverse, tensile and compressive strains and under a falling weight, these experiments being made on the same sample for each of the six conditions. The bending test with wrought iron joists showed substantially the same for all the conditions; the maximum loads carried showed differences, being highest in the natural condition and lowest when freshly pickled. Rusting also produces a diminution of strength, more apparent in the galvanised specimens than in those not galvanised. In the instances where the specimens were broken, the diminution in strength is said to be very decided in the pickled and perceptible in the rusted specimens. The figures are:—Breaking strain under condition 1, 35 tons; under condition 2, 33.9 tons; under condition 4, 32.7 tons; under condition 5, 29.6 tons, and under condition 6, 30 tons. The steel specimens showed results which follow the same law.

When iron is placed in acid, some of it is dissolved and hydrogen is liberated. This gas is supposed to be of the nature of metal, and as such it combines with and forms an alloy with the iron, which become quite brittle till the iron is heated and the hydrogen is liberated, when it regains its tenacity. If a piece of wire be broken when it has thus become alloyed with hydrogen, and the end wetted, the bubbles of gas may be seen rapidly passing through the water. This condition of things was observed and investigated by W. Johnson, of Manchester, and afterward by Prof. Osborne Reynolds. The latter showed that if an iron tube be closed at one end and filled with oil and placed in an acid solution, hydrogen is liberated from the outside, which passes through the wall of the tube, displacing the oil, so that the gas may thus be easily collected from the inside of the tube. There is a possibility, therefore, that when iron is rusting, the hydrogen liberated may similarly combine with the iron and render it brittle or reduce its strength, and this is a question of much importance to engineers.

Some interesting experiments in regard to the decrease in the strength of iron after being pickled and galvanised were recently reported. A dozen eye bolts, all precisely alike so far as could be perceived by external inspection, were carefully selected. Six of these eye bolts were laid to one side and the others sent away to be galvanised. A testing machine was not at hand, but six bolts were connected together, one being connected to each of the ungalvanised ones. Then they were placed between two pieces of iron and the nuts screwed up until the eye bolts broke. Invariably it was found that the galvanised eye bolts were the ones to break; not in one instance did the ungalvanised ones give way. Boat builders also state that galvanised iron is "rotten." They say that when great strength is required, select the iron and have the fittings forged by a good smith, but do not have them galvanised. Galvanised iron is frequently used in places where little strength is required, but where rust would be objectionable. For this purpose galvanised iron leaves nothing to be desired, but where the full strength of the material is desired and rust stains are objectionable, the object may be obtained by cleaning them with the sand blast process and afterward coating them by the cold galvanising process, both of which methods are becoming well known and largely used for the above purposes.

The foregoing may be of more or less interest, but I take it that what more nearly concerns foundrymen is:—"Does sand blast pay for foundry use?" I say yes. But as I said before, it is difficult to approximate on general work. I am safe in saying, however, that on ordinary iron, steel, brass and bronze castings one man, operating a sand blast apparatus consuming 120 cubic feet of air per minute, will clean more surface and remove more cores in a given time than is possible for from six to ten men to do with hammers, chisels and brushes. And the finished work left by the sand blast is infinitely

better than what can possibly be done by hand labourers. I have proved this repeatedly. I have never yet seen the burnt sand or scale that sand blast would not remove, and remove rapidly. Not only is it a great saving in time and labour in the actual cost of castings, but a further saving is made in castings to be machined. The removal of the oxide in itself is a great saving on tools, and in many cases the tools can be run at an increased speed. This particularly applies to milling cutters.

Difficult and intricate cores are readily removed and have greatly astonished some engineers. One peculiar thing in cleaning steel castings in which large quantities of wire nails are used is the cores. When subjected to the sand blast the sand is eaten away first and subsequently the nails will fall to the ground, sand blasted, perfectly clean and in condition to be used over again. I could give many instances that have come under my notice of the quick removal of cores, and will mention one that was accomplished in five minutes. This was considered to be a job of from three to four hours for one man with hammer and chisel. Quite a number of people who have adopted the sand blast recently and who previously used facings, have discontinued the use of such, and have assured me that the sand blast has enabled them to reduce the cost of their product. In conclusion I would say that the only objection to sand blast that can be found to its use in foundries is that it has an unpleasant trick of showing up defects and making them plainly discernible.

CONVEYING-BELTS AND THEIR USE.*

By Thomas Robins, Jr.

ABOUT six years ago the writer had occasion to visit a large magnetic iron-ore concentrating-plant, and then saw for the first time rubber belts used for conveying purposes. These belts were from 20 inches to 30 inches in width, and some of them were as long as 500 feet between centres. When I spoke of the enormous amount of material they handled with a small expenditure of power, the superintendent assented, but at the same time complained that although he bought the best quality of belts, the abrasion of the ore wore them out very rapidly, causing continually very large bills for repairs and renewals.

On close examination several interesting points were discovered:

1. It was noticed that the thin layer of rubber which covered the belt resisted the abrasion much longer than did a corresponding thickness of the cotton duck which formed the body of the belt; in fact, the life of the cover represented about one-half the life of the belt, although forming less than one-fifth of the total thickness.

2. Each layer or ply of duck wore out more quickly than the one preceding it, showing that the fibres were cut more easily under tension, and, of course, the tension on each fibre increased as the number of fibres bearing the tensile strain diminished.

3. The wear was greatest in a line along the centre of the belt. Frequently this part would be so quickly destroyed as to cause the belt to split in two longitudinally, though at the same time the portion nearer the edges was almost as good as new.

Noticing these facts, it became obvious that the functions of the cotton duck should be solely to give the belt tensile strength, and that it ought to be

* From a paper read before the American Institute of Mining Engineers.

so protected by some abrasion-resisting cover that it would not be injured by contact with the material conveyed. It is also evident that this protecting cover ought to be of extra thickness over the centre of the belt, in order to stand the harder work forced upon that part. Being engaged then, as now, in rubber manufacture, it was a simple matter to make a belt with a heavy rubber cover on the carrying side and thicker in the centre than at the edges.

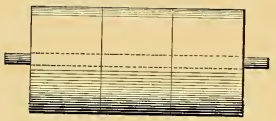


FIG. 1. THE OLDEST METHOD OF SUPPORTING CONVEYING BELTS.

This reinforced cover renders the resistance to wear equal in all parts of the belt, and although being merely the anticipation of a patch, like the brass toe-cap on the schoolboy's shoe or the two-ply seat in his trousers, it was, like them, deemed patentable.

The ideal conveying-belt would be like the celebrated "one hoss shay," which disintegrated so evenly and completely when its work was done that there was nothing left to repair or regret.

Wishing to ascertain what particular compound of rubber would make the most durable carrying-surface, I made a lot of small samples, each mixed differently, and exposed them to a very powerful sand-blast, which in its effect approximated the conditions to which the compound would be subjected in actual use, but it was more convenient for a large number of tests, being much quicker. The result of the first series of experiments indicated what grades of gum and what adulterants had better be left out, and also showed something that was very gratifying, namely, that there were certain adulterants which could be used in sufficient quantities to bring the cost down to a reasonable figure. I then made a second set of samples, following in the mixture the formula used in the more successful ones of the first set, but each new one was an attempt to improve upon its prototype.

Some of the samples, owing to more intelligent methods in mixing them, proved so durable that the sand-blast test became too tedious, and a more severe and expeditious one was needed. This was found in exposing a disc of the rubber 6 inches in diameter by $\frac{1}{8}$ of an inch thick to a heavy falling stream of crushed ore. The ore averaged about $\frac{3}{4}$ of an inch in size, and was delivered in a compact and heavy stream from the end of a very fast-moving belt. The sample was so fastened to a board as to receive the whole stream of ore and immediately deflect it. In this way the rubber came in contact with 200 tons of ore per hour, of which each fragment was delivered with considerable force full upon it. At first it was easy to see the comparative loss of weight after the sample had been exposed to the ore for an hour or two. In the next series results were very apparent after a day's run, but later, as results were developed which I was willing to accept as final, it became necessary to weigh each disc before and after the exposure, and thus learn the percentage of loss.

Having at last decided upon the proper compound for the carrying-surface, I applied it to the belts, and I may

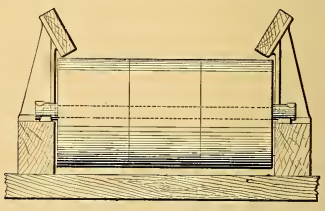


FIG. 2. IDLER PULLEYS WITH SKIRT BOARDS ADDED.

say that every belt made since that time, which was in 1892, is in good order to-day. In many cases, too, the belts which they replaced had been completely destroyed in three months' time under exactly similar conditions.

AN APPROVED CONVEYING BELT OUTFIT.

There are four principal methods of supporting conveying-belts. First we will consider the oldest method, in which the belt lies flat upon a straight-faced, horizontal pulley, as shown in Fig. 1. On account of the liability of the material to roll off the belt, this form is suitable only under certain conditions as, for example, in the conveying of grain which is so light that the resistance of the air makes it crowd together in the centre of the belt. The belt can not be heavily loaded, and the feed must be so regulated that an even amount may be delivered to the belt at all times. If the material is below ¼-inch in size, the speed may be as high as 300 feet per minute. In carrying larger stuff on flat belts the speed must be lower ; but the most necessary thing is to keep the belt very tight, so that the material may not be jarred off in passing over the idler pulleys. This, of course, increases the strain on the bearings, and from that fact, together with their low efficiency compared with systems to be described later, we may consider flat-running belts as being out of date.

The second method (Fig. 2) is somewhat like the first, but with the addition of skirt-boards at the sides to increase the capacity of the conveyer. This method of rigging belt-conveyers is in great vogue among brick-makers and others who handle clay. It will be easily seen that the material must collect between the skirt-boards and the belt, and that, as it hardens, it will cut a strip off each side. The common practice is to start with a wide belt, and move the skirt-boards in as fast as these strips are cut off. When the width is so reduced as to render the conveyer totally useless, wheelbarrows are called into play until a new belt can be procured, and the entire process recommenced. This method is so entirely bad, that I refrain from further description. It is only fair to say, however, that the skirt-boards fill one useful purpose, as it is the practice of the men shoveling into the belt to rap their shovels against the boards in order to get rid of the sticky clay.

The third method is a slight improvement upon the last, in that a trough is made by raising the sides of the belt

instead of using boards as described above. The conical pulleys used for this purpose are shown in Fig. 3.

This method has an obvious fault. By reason of the difference between the two diameters, the outer edge of the

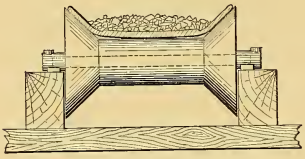


FIG. 3. CONICAL SIDE IDLERS.

pulley goes twice as fast as the inner edge. This causes a slip which soon wears out the under surface of the belt. For belts not wider than 14 inches this form is not bad, for, with small belts, the weight on the pulleys is light, and the effect of the slipping is consequently less severe.

The fourth, and best form of belt-support, is composed of three pulleys, one carrying the middle or bottom of the belt, and one on each side with its axis at an angle of about 45°. The shafts of all three pulleys are held in a pair of combination bearings which can

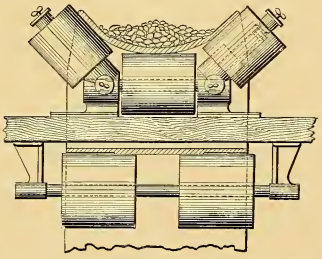


FIG. 4. THE BEST METHOD OF SUPPORTING CONVEYING BELTS.

be adjusted to different widths of belt. I never supply any other form of support for belts wider than 14 inches, and when I refer to troughed belts in this paper, it is to be understood that the sides are raised by means of these angle-pulleys, one common form of which is shown in Fig. 4.

There has been no mention hitherto of the means of supporting the empty part of the belt on its return. This is done by a single flat pulley of the kind shown in Fig. 1, or with a pair of smaller pulleys with an interval between them, as shown in the lower part of Fig. 4.

It is sometimes possible to save money in constructing a long conveyer by combining the first and last methods of belt-support referred to. If the belt were run flat the whole distance, it would need to be so wide that the extra cost of the belt would be about equal to the money saved in using the cheaper flat form of pulleys; but by placing a set of troughing pulleys between every

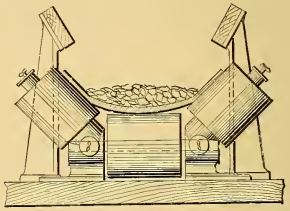


FIG. 5. THE BEST METHOD OF SUPPORTING BELTS WITH SKIRT BOARDS.

fourth and fifth set of flat pulleys, or at such other interval as may be found advisable, the load is so centred on the belt at each of these points that it has no time to overflow before it is again centred between the next pair. The use of a very wide belt thus becomes unnecessary, but the conditions are not always favourable to this plan.

On some conveyers, it is often advisable to have, at intervals, a pair of idlers, running on a vertical axis, or inclined inward, so as to make a right angle with the edge of the belt. These will serve to keep the belt straight on the pulleys if there is any tendency to run toward one side, but with a good belt and strong, true supports, these extra pulleys are not needed. (See Fig. 6.)

The large pulleys at the end of the

belt should be slightly crowned on the face, and the pulleys should not be less than 4 inches wider than the belt. The driving-pulley ought never to be less than 30 inches in diameter, and in the case of long wide belts 48 inches is advisable, as it allows the first return pulleys to be so placed as to give the belt a very large arc of contact on the driving-pulley. (See Fig. 7.)

Whenever it is possible, it is better to have the driving-pulley at the deliv-

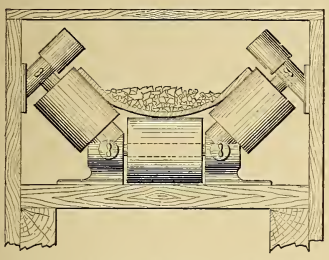


FIG. 6. METHOD OF FIG. 4, WITH GUIDE PULLEYS ADDED.

ering end of the belt; but, if it must be at the receiving end, a triple set of pulleys connected by gears can be easily arranged which renders slipping impossible with the longest and heaviest loads. I believe that this scheme was first used by Mr. S. H. Edwards, Superintendent of the Magnetic Iron-Ore Co., at Benson Mines, New York. (See Fig. 8.)

The proper distance between the sets of idler pulleys is an important factor in the economical running of the belt. I believe that the troughing-pulleys should be from 4 to 6 feet apart, according to the weight of the load, and that for the return belt there should be pulleys placed under every alternate set of troughing-pulleys, which would make the lower pulleys from 8 to 12 feet apart.

To me, one of the most wonderful things in connection with this subject is the exceedingly small amount of power required to move enormous quantities of material. The power required, in one case, to run a conveyer, which carries 1000 tons per day a distance of 180 feet, and elevates it 40 feet while doing so, is all transmitted by a torn and frayed little 5-inch belt, which takes its power from a pulley on the shaft, and transmits it to a pulley alongside the head-pulley of the belt. The power is here divided, part of it going over a sprocket-chain to help drive a large dumping-apparatus. Yet the entire amount of power employed for both purposes does not exceed four horse-power.

I would like very much to give some rule for determining the exact number of horse-power required for conveying-belts running under different conditions, but I find it impossible, owing to the number of variable quantities which make up the load. One of the most important of these points is based upon the distance between the sets of troughing-pulleys. If they are too far apart the belt sags down between, which materially increases the load. If, on the other hand, the idlers are too near together, the extra number of bearings makes another sort of resistance to be overcome. No general rule can, therefore, be made by which the required horse-power can be accurately determined.

It is a simple matter to determine the necessary belt-weight and speed to perform certain duty when the weight per cubic foot of material is

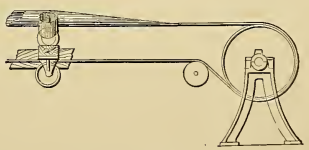


FIG. 7. RETURN IDLER.

known. If the belt is troughed, it is safe to estimate that the load itself will cover one-half of the belt's total width, and that the depth in the centre will be one-quarter of its own width. The area in inches of a cross-section of the load (which we may consider an inverted triangle) will, when multiplied

by 12, give the number of cubic inches of material borne by the belt on each running foot of its surface. Multiply this result by some estimated speed, to

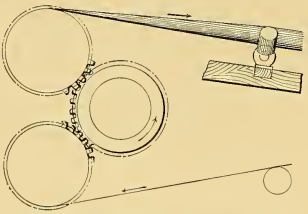


FIG 8. DRIVING LONG CONVEYERS FROM RECEIVING END.

get the quantity in cubic inches that the belt will deliver per minute, and then reduce this to the number of feet, yards, pounds or tons delivered per hour, or to other convenient terms. (See Fig. 9.)

For example :—To find the number

FIG. 9. DIAGRAM EXPLAINING METHOD OF CALCULATING WORKING LOAD.

of tons of material weighing 100 pounds per cubic foot that can be delivered by a 24-inch belt running 250 feet per minute : —

As the belt is 24 inches wide we may safely consider the load as being a triangle standing on its apex and having a base 12 inches wide and a height of 3 inches. Therefore, the area of its cross-section will be 18 inches, and there will be, $18 \times 12 = 216$ cubic inches on each foot of the belt. As the speed is 250 feet per minute, there will be delivered from the end of the belt 250 times 216 cubic inches, or 54,000 cubic inches per minute. This is equal to $31\frac{1}{4}$ cubic feet per minute, or 1875 cubic feet per hour, weighing 187,500 pounds, or about 93 tons per hour.

To save some of the steps referred to above, the following formula may be used. If we let A = width of belt, then $\frac{3\,A^2}{8}$ = number of cubic inches carried on each running foot of the belt. If a belt is run flat it will carry about one-third as much, or $\frac{A^2}{8}$. It is well to remember that when the width of a belt is doubled, it will carry four times as much material, and when it is tripled it will carry nine times as much.

The following table will be found of service in determining the capacity of conveyer-belts. In regard to this table I wish to say that the results shown are based upon a continuous and even delivery of fine material to the belt. As this is often unattainable in practice, it is well to prepare for uneven and large pieces and for irregular feed by allowing a margin in either belt-width or speed, the two factors which govern the capacity of the belt. The widths of belting in most common use are 22, 24 and 26 inches, and the average speed is about 300 per minute. I am inclined to favour higher speeds, especially for elevating at an angle, as it requires less power to lift a small sized load at a high speed than the same amount of stuff per hour in a larger sized load at a low speed. A good speed for level

FIG. 10. CROSS SECTION SHOWING STRUCTURE OF CONVEYING BELTS.

work is 450 feet per minute ; at an angle, 650 feet is not at all too fast ; and I have seen belts working smoothly at 900 feet per minute and at an angle of 27 degrees. Such speed as this, however, is hard on both the belt and idlers.

Having decided upon the proper width of belting for the duty to be performed the next points to be settled are the proper thickness for the belt and for its protecting cover. The necessary number of plies depends upon the length and width of the belt, the giving all the advantages of a heavier belt but at a lower cost. (See Fig. 10, B.)

At the point where a belt receives its load, it gets as much wear as it meets with in all the rest of its journey. A few points should be borne in mind in

Table Showing the Number of Cubic Feet of Material Delivered in an Hour by Different Widths of Troughed Conveying-Belts Traveling at Various Speeds.

SPEED, PER MINUTE, IN FEET IS SHOWN IN THE LINE NEXT BELOW THIS.

Width of Belt in inches.	100.	150.	200.	250.	300.	350.	400.	450.	500.	550.	600.	650.	700.	750.
12	187.5	281.2	375.0	468.7	------	------	------	------	------	------	------	------	------	------
14	255.2	382.8	510.4	638.0	765.6	------	------	------	------	------	------	------	------	------
16	333.3	500.0	666.6	833.3	1000.0	1165.5	1333.2	------	------	------	------	------	------	------
18	412.8	619.2	825.6	1032.0	1238.4	1444.8	1651.2	1857.6	2064.0	------	------	------	------	------
20	520.8	781.2	1041.6	1302.0	1562.4	1822.8	2083.2	2343.7	2604.0	2864.4	------	------	------	------
22	630.2	945.3	1260.4	1575.5	1890.6	2205.7	2520.8	2835.9	3151.0	3466.1	3781.2	4096.3	4411.4	4726.5
24	750.0	1125.0	1500.0	1875.0	2250.0	2625.0	3000.0	3375.0	3375.0	4125.0	4500.0	4875.0	5250.0	5625.0
26	880.2	1320.3	1760.4	2200.5	2640.6	3080.7	3520.8	3960.9	4401.0	4841.1	5281.2	5721.3	6161.4	6601.5
28	1020.0	1530.0	2040.0	2550.0	3060.0	3570.0	4080.0	4590.0	5100.0	5610.0	6120.0	6630.0	7140.0	7650.0
30	1170.1	1755.0	2340.2	2925.2	3510.3	4095.3	4680.4	5265.4	5850.5	6435.5	7020.6	7613.9	8190.7	8775.7
32	1333.3	2000.0	2666.6	3333.3	4000.0	4666.5	5333.2	6000.0	6666.5	7333.1	8000.0	8666.6	9333.1	9997.5
34	1505.2	2257.8	3010.4	3763.0	4515.6	5268.2	6020.8	6773.4	7526.0	8278.6	9031.2	9783.8	10536.4	11289.0
36	1687.5	2531.2	3375.0	4218.7	5062.5	5906.2	6750.0	7593.7	8437.5	9281.2	10125.0	10968.7	11812.5	12655.2

weight of the load and the distance between the sets of idler pulleys. The common practice is to use 4, 5, and 6-ply belts.

The thickness of the rubber cover should be based upon the character of the stuff to be carried. For hard material, weighing over 50 pounds per cubic foot, the cover should not be less than $\frac{1}{4}$ inch in thickness. With the patent reinforced cover referred to above, it is possible to have this thickness at the centre where it is needed, allowing it to taper off to $\frac{1}{16}$ inch or $\frac{1}{8}$ inch at the sides where the work is lighter. This, of course, makes the cost lower than if the same thickness of cover extended the whole width of the belt. The belt with the reinforced cover referred to is shown in Fig. 10, A. There is now an improved form of this belt which combines the advantages of this thickened cover with stiffened edges which make the belt bend properly at the centre and preserve its troughed shape between the sets of idler pulleys and also give it such firmness at the edge that a mere touch against the steering idlers serves to keep it running true. This stiffening is done by running two or three plies of duck a part of the way in from the edges, connection with this part of the conveyer. The material should not be allowed to drop vertically upon the belt, but should instead be so guided by an interposed chute as to strike it with as nearly as possible the same speed and, of course, in the same direction as that of the belt itself. This is much the same principle as that which causes a man who wishes to board a fast moving car to run along a few feet before jumping upon the step, except that in the former case it is the wear-and-tear upon the vehicle or belt which is avoided instead of injury to the passenger.

If ore or rock is carried, there is bound to be wear wherever it touches. It is well, therefore, if it has to fall any distance, to let its force be broken by striking first against an accumulated pile of itself and then roll off on to a chute, whence it may slide quietly upon the belt and not move until it reaches the end of its journey. Fig. 11 shows the device in use at the N. J. and Penn. Concentrating Works, at Edison, New Jersey.

The chute should be made of cast-iron with sides, and should be so wide that the ore or other metal cannot get jammed. The objection to a wooden

chute is that the broken stone or ore does not slide properly upon it, but runs down in a succession of jumps, that are apt to carry it over the side of the chute or off the belt.

A device is shown in Fig. 12 for loading a belt under a crusher, from which falls both coarse and fine stuff. The upper incline represents a grizzly or screen of iron bars which allows nothing larger than 1-inch to go through. The small stuff slides down the lower chute, and forms a bed on the belt to protect it from the impact of the heavier pieces.

There are many ways of joining the

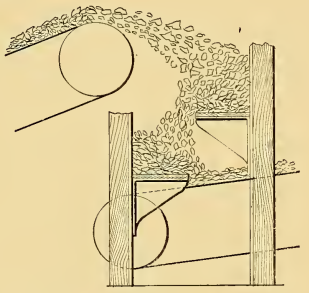


FIG. 11. DELIVERY OF COARSE MATERIAL FROM ONE BELT TO ANOTHER.

ends of carrying-belts, the most common being by the use of metal belt hooks consisting of a set of teeth cast together with a metal back. These have to be destroyed if the belt needs taking up, and a better plan is shown in Fig. 13. The thin steel plates are laid upon a strip of thin leather or canvas which covers the opening in the belt and thus prevent leakage. Staples are driven through the holes in the plate and clinched. In breaking the joint the staples are easily cut with a cold chisel, but the plates themselves can be used an indefinite number of times.

The simplest method of lubricating the bearings is by means of compression grease cups which are dust proof and very economical. They are screwed into the ends of hollow shafts and a man without stopping can give the handles a turn as he walks along the belt, and this only has to be done once a day at most. Grease costing about four cents a pound is generally used.

Some of the purposes for which conveying-belts are used are the carrying of trap-rock and limestone in stone-crushing plants, charcoal and ashes in sugar-refineries, ore in concentrating-

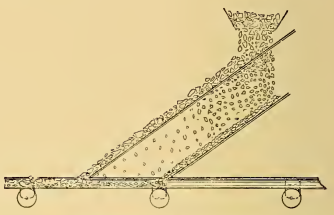


FIG. 12. COMBINATION OF GRIZZLY AND BELT.

plants and mines, earth and stone in large excavations, blocks and logs of wood in pulp-mills, clay in brick-yards, coal in breakers, yards, large power-plants and culm-piles, tobacco in process of manufacture, customers' packages in large retail stores, grain in elevators and flour-mills, boxed goods in coffee-mills, phosphate-ore in the southern mines and chemical fertiliser in plants all over the country. These

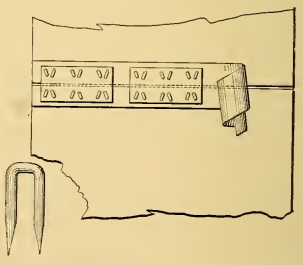


FIG. 13 JOINING ENDS OF CONVEYING BELTS.

are only a part of their uses, but the list of other purposes for which, though not employed, they are equally suited, and must some day be applied, would be a very much larger one.

Belts generally cost less to install than any link-belt or other metal conveyer, and the cost of maintenance is so much less that there is simply no comparison between them. In addition to this, they run noiselessly, instead of making a perpetual and deafening racket, and no owner's ears can become oblivious to a banging and crashing of which every vibration means wear and depreciation, as well as loss of power.

You may say, "If this belt method of conveying is all that this man claims, why hav'n't we heard more about it? Why isn't it used more widely?" My answer is this:—The various systems of sprocket-chain, metal pan, trough and screw conveyers and the overhead cable systems have all been owned by manufacturing concerns who make them known by advertising, undertake their construction and installation, and guarantee them. As to conveying-belts, no fundamental patents on the principle could be secured; and because a belt conveyer is composed of two parts which are about equal in value and the products of entirely separate kinds of manufacture (I refer to, first, the iron pulleys and other supporting parts, and second, to the belt itself), no iron man felt like pushing the sale of a conveyer, when he knew that some rubber manufacturer would share equally in the profits, and the rubber man would, doubtless, have felt the same if, with his less extensive knowledge of machinery, the thought ever occurred to him at all.

And so, between them, the belt conveyer has been neglected except where its merits compelled the recognition of a few wide-awake and self-reliant engineers. It has been the property of no one. Nobody's living depended upon its exploitation. It was to the interest of no one to stand sponsor for it; to develop, push it and perfect it. There are no data published about it, and each man who uses it to-day is practically the inventor of his own apparatus, which he has brought to its present state only after an expensive and vexatious experience. If an engineer to-day has a conveying-problem to solve and the thought of a belt occurs to him, immediately after come the questions:—What kind of a belt? What width? How should it be run? On what? At what speed? Where can I find out? Being unable to answer any of these questions, and not caring to try experiments, his natural inclination is to state his needs to the well-known manufacturers of conveying apparatus to make a contract with one of them, thereby shifting the responsibility as soon as possible. The load of responsibility is apparently charged for along with the apparatus, but even the high price of the latter contains no suggestion of the great and continual expense incurred in running and keeping it in order.

I do not wish to appear as condemning universally the use of all metal conveyers, for there are, indeed, some conditions for which they are better suited than are belt-conveyers. I may mention, for instance, places where the point of delivery must be constantly and quickly changed. With iron conveyers this is accomplished by the removal of a section of the iron trough, while a belt requires a movable framework containing two pulleys. This dumping apparatus can be moved to any point in the belt's length, but it is neither as cheap in construction nor as quick in operation as the plan adopted with metal conveyers.

Nor do I condemn the great ingenuity which has made possible even the poor performance, by metal conveyers, of duties for which by their very nature they are unfitted. I only want to show that there are many places where other conveyers are now used for which belts could be substituted with economy.

THE FUTURE OF POWER DEVELOPMENT.

By George S. Strong.

THE following article has seemed to the writer as desirable to call attention to what are to be our future power supplies and to correct the many false impressions in the mind of the public as to what are original sources of power and what are merely means of storing or transmitting power after it is generated. A large majority of people who are not engineers have an idea that electricity is power, or a source of power supply, and we find the same impression regarding compressed air. For illustration, nearly a page of one of the daily newspapers was recently devoted to compressed air, with the heading, "Electricity's New Rival in the Field. As the Magnetic Spark has Driven Steam from the Ground, Compressed Air has Entered the List to Battle for Popularity."

There could not be anything more misleading. Electricity has not driven, and is not driving, steam from the field, but has greatly added to its use, and is entirely dependent on steam or some other original source of power for its existence. One of the best illustrations of the sources of power at the command of the human race, was given in a paper read by Sir William Thompson, the celebrated English scientist, before the British Association, at Manchester, in 1881, in which he classified the available powers as water power, wind power, steam, gas or heat engines, deriving their power from the burning of coal or the gases derived from coal, tidal energy and animal power. All of these, except tidal energy, are derived originally from the heat of the sun.

Water, owing to the isolated location of many large water powers and to the cost of harnessing and conducting it long distances, is probably not so likely to play a great part in the future of industrial enterprises. This is borne out by the facts in connection with the development of power at Niagara, where the investment in proportion to the horse-power developed has been so great as to make the use of this power for large enterprises prohibitive as compared with power developed at or near the coal mines of Pennsylvania, Ohio and other parts of the United States, for example, where coal is found in large deposits and over a very wide area.*

Next on Sir William Thompson's list comes wind power. This, in the

* With reference to this statement by Mr. Strong it seems only proper to call attention to the fact that two great industries,—the making of aluminium and of carborundum,—have become located at Niagara Falls and are supplied with power from the famous installation there. This is all the more noteworthy because of their previous location at Pittsburgh, in Pennsylvania, in the heart of the cheap American coal district. With coal at 60 cents a ton in Pittsburgh, so it is stated on good authority, their electric current cost them nearly three times what they are now paying at Niagara Falls.—THE EDITOR.

early ages, played a very important part and, as pointed out by him, was, in 1881, still playing an important part, as at that time nearly three-quarters of the commerce of the world was handled in sailing ships, and he predicted that in the not very distant future, when the coal fields of England and other parts of Europe would be exhausted, large wind engines, driving electrical generators, would be used, which would store their energy in batteries, to be drawn on at will. But, at present, the wind engine, like the development of large water powers, makes the cost of the power so developed expensive for large uses. It has, however, the advantage over water power of being everywhere at command if a sufficient elevation be reached.

Next comes steam, gas or heat engines. The steam engine has been man's best friend and will, doubtless, continue to hold its own for many years to come for many purposes, and to those who have given much thought to, and are thoroughly familiar with, the situation, the many articles that have appeared in the daily press as to steam being superseded for driving long distance express trains, seem ridiculous. In the first place, there is not an electrical generating plant for power purposes to-day in operation that is generating a horse-power in regular work on two pounds of coal per horse-power per hour,—not to say that a first-class steam engine cannot be made to do better when a full load is given at all times, but on a varying load the consumption of coal will be nearer four pounds than two. Then comes the loss due to transmission and conversion of electricity into power. The same may be said of compressed air, and in neither case will an average of more than 60 per cent. of the power of the original engine be delivered on the shaft of the secondary motor at the end of the wire or pipe.

The best compound locomotive, on the other hand, working steam from a modern wide fire-box boiler, or where a sufficient grate area is provided to enable the engine to steam freely with a large exhaust, can be made to work down very close to, and, indeed, inside of, two pounds of good coal, and here the power is delivered directly to the axle and there are no losses, except those incidental to all steam engines with unequal loads. The one great advantage claimed for the electric locomotive over the steam locomotive, was an even pull on the draw-bar, and an even pressure on the rail, but recent improvements in the locomotive have obviated this difficulty, and afford the possibility of a perfectly even pressure on the rail, and a perfectly even pull on the draw-bar, and a boiler so constructed as to burn all of the gases and do away with all the smoke and cinders, so that it would be as pleasant to ride behind such a locomotive as it would be behind an electric locomotive.

Considered from an economical standpoint, the cost of an electrical locomotive of 1500 H.-P. would be about $50,000 (£10,000); the generators to drive it would cost $30,000 (£6000), and the wiring of the track with an underground system would cost $30,000 (£$6000) per mile. Assuming therefore, that we have 100 miles of road, and require four tracks to be wired, the wiring would cost $12,000,000 (£2,400,000); one hundred electric locomotives would cost $5,000,000 (£1,000,000), the generators $3,000,000 (£600,000), engines $3,000,000 (£600,000) and boilers $3,000,000 (£600,000), or a total of $26,000,000 (£5,200,000), to handle modern fast express and freight trains over 100 miles of road, as against one hundred balanced compound locomotives at $12,000 (£2400) each, or $1,200,000 (£240,000) as compared with $26,000,000 (£5,200,000).

If the electrical locomotives are furnished free coal, a railroad company could not afford to own them and pay the interest of $1,320,000 (£264,000) per year on the investment, while if each of the compound locomotives made an average of 400 miles a day for 365 days in the year, and used eight tons of coal at $3 (12 shillings) per

ton, the coal would cost but $876,000 (£175,200).

Assuming, as we may from past experience, that electrical power plants cannot be depended upon to produce better results in regular railroad work than they have done in street car service, we should have to expect to burn more than the same quantity of coal in the electrical plants than in the steam locomotives, so that we should have the $1,320,000 (£264,000) plus at least $876,000 (£175,200), or $2,196,000 (£439,200), as the cost of interest and fuel for the electric plant and $72,000 (£14,500) plus $876,000 (£175,200), or $948,000 (£189,600), as interest and cost of fuel for compound steam locomotives.

Taking gas engines, which derive their energy from coal or other carbon gases or from hydro-carbon gas, we open up a comparatively new field, for while the gas engine has been known and used for many years in a small way, and with remarkably good results as far as economy goes, it is only since a short time that its merits have been fully appreciated. It is now, with the introduction of new methods of gas production, by the use of by-product-saving appliances that go far towards paying the original cost of the fuel, and thus reducing the cost of the fuel gas to a very low figure, doing much to solve the problem of cheap and effective power.

As these gases are low in illuminating qualities, they are very much better suited to give the highest efficiency in the gas engine. Another gas that has recently been discovered has remarkable qualities under compression and can be reduced in volume 400 times at 800 pounds and when expanded will burn with twenty times its volume of air, requiring only 0.4 of a pound of it when compressed to develop one horse-power per hour. Each cubic foot of it at this pressure weighs 30 pounds and, therefore, contains 75 H.-P. hours, being the greatest storage of energy ever known for a given weight.

This opens a wonderful field for the development of power for motors for tram-cars and other classes of motor vehicles, as well as pleasure boats. Gas engines, working with this new fuel gas, are likely to have a very large use in all stationary work and for propelling boats, and it may not be beyond the bounds of possibility to drive ocean steamers and locomotives of the future by gas engines. It is especially suited to the generation of electricity, particularly when the electric plant is located at inaccessible points where it cannot be reached by boat or rail and where coal would have to be carted and from which ashes would have to be removed.

The gas producer can be located at the railroad or on the water front and a not very expensive pipe line run to the power plant, the gas travelling without cost except interest on the pipe line. The water for cooling the jackets of the gas engines can be used over and over again, and with proper arrangements for cooling the water, only a small quantity would be required, while the steam engine needs a large quantity for condensing.

A ton of soft coal will produce 125,000 cubic feet of gas of 160 heat units, about 45 feet of which will produce a horse-power in a properly designed and well constructed gas engine, or about 2777 H.-P. hours for each 2240 pounds of coal. At the same time, about 90 to 100 pounds of sulphate of ammonia are recovered from this coal, which, at present, is worth about $50 (£10) per ton, which, after paying all the cost of operating the producing plant and making the gas, yields about one cent (½d.) per pound. The gas from blast furnaces can also be used and is found to give wonderfully good results, considering its poor quality.

Recent discoveries in mechanical power transmission have made it possible to run a gas engine at full speed in one direction and vary the speed of the driven shaft from zero to full speed in either direction without frictional gearing and without appreciable loss of power. This makes the gas engine applicable to any purpose to which the steam engine

is suited and makes it especially suitable for boats, street cars and motor waggons.

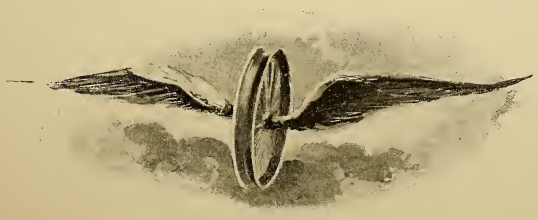
Recent improvements in the construction of pumps have also made it possible for a pump to be run at the same speed as the piston of a gas engine, or from 600 to 1000 feet per minute and permit the direct connection of the connecting rods of the engine with the pump. This makes the gas engine, with such a pump, the most economical pumping engine yet devised, and while 135,000,000 foot-pounds is about the limit of the steam pumping engine, the gas engine is likely to give over 200,000,000 duty.

Considerable has been said and written about the combination of the gas engine with electricity for driving trains, as against the steam locomotive. This involves the introduction of the losses by electrical transmission above mentioned and the original cost of the electrical equipment and does away with the advantage of independent units of power, which has been the one cause of the return to the compressed air idea. It is altogether more probable that the gas engine will be used direct as a locomotive, commencing with the smaller motors for tram-cars and motor waggons, and gradually grow in favour as its utility is demonstrated, until the full-fledged railway locomotive is developed, carrying its gas producer on a tender, entirely automatic in its operation.

The fireman, as such, will be done away with and become the engineer's assistant in oiling and looking after the operation of the machinery. This will bring the coal consumption per horse-power per hour from about 5 down to about ⅞ lb. of a pound, and it will be done without adding greatly to the present first cost. For street car work, compressed gas with the gas engine makes it possible to run a car 750 miles with one charge and at a cost of less than one-third what it now costs to run the same car by electric motor, or one-third what it is likely to cost for the compressed air motor.

With the introduction of this gas motor applied to properly designed cars or coaches, the necessity for the track with its consequent blocking owing to a single line of travel, disappears. With smooth pavements and rubber tires the track would not be required; and with independent busses or cars running without tracks, if an obstruction is met, it can be gone around and the journey continued without delay. The injury to streets, owing to the laying of tracks that are a continual menace to ordinary vehicles, can, too, be avoided.

As to the last named source of power, aside from animal power,—tidal energy,—this is not likely ever to be used to any great extent in many places, because of insufficient rise and fall to make tidal locks of much use. As to animal power, it has had its day and for all large uses, as well as for the ordinary business of cities, the horse will soon disappear except for pleasure.



SOME FUEL PROBLEMS*

By Joseph D. Weeks.

THE primary problems of civilisation are material ones; their answers are writ in fire. When these problems in their higher aspects have pressed for solution, it has been out of the burning bush that the Divine voice has spoken, or in the cloud and smoke that the Divine finger has traced the rules by which these problems shall be solved. It is with the material problems, however, that we, as engineers, have to deal.

It is by fire that these problems are solved. With a marvellous insight into the secrets of power the Greeks made Prometheus, who stole fire from heaven to bestow it upon mortals, the author of civilisation. In the words which Æschylus makes him utter as he lay bound on Caucasus, "All arts among the human race are from Prometheus," and it is from the "bright play of fire that all arts spring." In this myth is thinly veiled the origin of the mechanic arts, and is dimly suggested the part fire has played in their development. The myth also foreshadows the triumph of civilisation, by the aid of fire, over the forces of nature, for there should one day be invented a flame more potent than lightning, before whose power Jupiter himself "should fall dishonoured."

On the part that fire has played in civilisation we need not long dwell. For most of the centuries, indeed, up to the day when boiling water told its secret of power to Watt, its use was chiefly its primary one, to heat and light, and not its secondary one as a source of power. Its chemical effect and some of its direct mechanical uses were known, as well as its calorific effects. It cooked the food, but it did not drive the plow nor swing the scythe, nor thresh the grain, nor grind the meal; it smelted the ores, but it did not drive the blast; it heated the iron, but it was the brawny arm of the smith or the force of the falling water that hammered it into shape, while even as in Prometheus' time the land was still traversed "with steeds in cars obedient to the rein," and the "canvas-winged chariots of the mariner" still roamed over the ocean. In a word, while fire gave heat and light, the sources of power through all these centuries were muscle and wind, and falling water.

It is not these primary, but the secondary and even more remote effects of fire that have caused civilisation to move with a quicker step. While all the marvellous effects of fire, which have been for ages the possession of humanity still remain as among its greatest endowments, it is as a source of power that fire in the last hundred years has been of such inestimable value. The beginning of its era of power was Watt's invention of the steam engine, for which the first patent is but one hundred and thirteen years old. The science of thermo-dynamics, based on the principle of the conservation of energy, one of the most important advances ever made in scientific knowledge, was created as late as the years 1845 to 1855. Even what we have learned in the century just closing as to the power of fire is as nothing to the stupendous power

* From a presidential address delivered before the American Institute of Mining Engineers.

of this agent that shall yet be revealed. It is quite needless to say that as back of this power is heat, and back of the heat fire, so back of the fire is fuel, and that for the civilised world fuel is but another name for mineral or fossil coal, and that for us the fuel question concerns itself chiefly with the possession, production and uses of coal.

There are other fuels than mineral coal, as petroleum and natural gas and the vegetable fuels. Indeed, the fuel question in England at one time, and not many years ago, especially in the iron trade, was a question of charcoal; but for furnishing the world's heat and doing the world's work none of these other fuels cut any figure except in restricted localities.

There are also other sources of power, as light, and wind, and water-flow, and muscle, and were these as willing, as constant and as untiring and tractable servants as heat from fuel, the power that could be derived from these natural forces is so vast that the problem of power would be solved; but there are night and clouds to stop the work of the light; the wind is fitful; it does not always rain, and muscle tires; but night and day, in storm and calm, in dry and wet, and at the end of the longest and weariest day, fire from coal will always answer the demand for power. Nor can we yet call into play that limitless power we call "solar energy," of which we know so much, with which now we can do so little. In our present impotence, coal is mightier to do our work than even this source of all power. The power problems to-day, then, are fuel problems, and fuel is mineral coal.

The world has a vast store of this mineral fuel—coal. How much, no one knows. But, vast as are these stores, the consumption in certain countries has been so great that nations have affrightedly asked to know how long the supplies would last. In England the question was discussed by such authorities as Sir William Armstrong before the British Association, Mr. Jevons in his work on The Coal Question, and in Parliament by John Stuart Mill and Mr. Gladstone. As the result of these discussions, the alarm over the probable exhaustion, in the not distant future, of its coal supplies was so marked that a royal commission was organised, who, arguing from several premises, estimated the duration of the supply at various periods, from two hundred and seventy-six years to over twelve hundred years.

But the consumption of coal in Great Britain has increased at a rate much in excess of that upon which the lowest estimate of the royal commission was based. In 1780, about the time the steam engine was invented, it was some 6,500,000 gross tons a year. It had arisen to 27,000,000 tons in 1816; to 50,875,000 tons in 1850; to 84,042,698 tons in 1860; to 112,875,525 tons in 1870; to 146,969,469 tons in 1880; to 181,614,288 tons in 1890, and to 188,277,525 gross tons (210,870,828 net tons) in 1894. The result of the discussions on the subject of the duration of the coal supply of Great Britain was the conclusion that if the output increases in the same ratio as it has for twenty or thirty years, the coal will be exhausted in a little over a century. These estimates are now regarded as excessive, as it is conceded that there is in each nation a limit to industrial development which, without considering the great economies in the use of fuel, will also limit the expansion of coal production. M. Gruener places this limit for England at 250,000,000 tons, which supposes a mining population of a million miners and a working population of five millions.

In the United States the production of coal has been increasing in a much greater ratio than in Great Britain. We cannot go back to the eighteenth century and give figures of production of coal, nor is that necessary in order to indicate how enormous has been the increase in its production and consumption in the United States. At the tenth census, 1880, the production of coal in the United States is reported at 71,481,570 net tons; at the eleventh census, 1889, it had risen to 141,229,513 net tons, nearly double; and in 1893, according to the report of Mr. E. W. Parker, of the United States Geological

Survey, it was 182,352,774 net tons, an increase of more than two and one-half times in thirteen years, doubling about every five years.

Similar increases could be shown for the other great coal producing countries, as Belgium, Germany, Austria, France and Russia. The world's demands for heat and power are increasing marvellously, while the world's supply of coal is a definite quantity, and it is an evident proposition that with the exhaustion of its coal not only will the power and influence of a nation decline but even its existence may be imperiled. The fuel problem, therefore, is not only an industrial one, but a political and politico-economical one of the greatest importance.

As the amount of coal in the earth's strata is a fixed definite quantity, in discussing the fuel problem we cannot proceed on the assumption of an increase in this quantity. We may discover deposits of which now we have no knowledge; but this does not add to the world's coal supply, but only to our knowledge of where that supply is stored. Some coal may still be forming in peat bogs; but the amount so being formed or that will be permitted to develop into coal will hardly be worth considering. It is evident, therefore, that an increase in the actual quantity of coal stored in the earth is not a factor of the fuel problem.

It is possible, as has been suggested, that other sources of power, and even of heat, such as chemical action and solar energy, especially the latter, may be, and no doubt will be, largely utilised in the future; but these are questions it is not within my purpose to discuss, and the day when these and other sources of power will be largely used will be when the supply of coal is very much reduced and its value very much increased.

As, therefore, we can expect no increase in the amount of the world's supply of coal, the fuel problem is to increase the efficiency of that we have, to make each ton of coal that remains in the hills do a much greater amount of work than it now does. In a word, the fuel problem is to reduce the waste and increase the efficiency of the coal we possess.

This problem divides itself into three distinct parts—that is, problems connected with,—

1. The mining of coal and its preparation for market.
2. The use of coal.
3. The products of the coal other than heat.

These problems all concern waste. First, as to the problems relative to mining the coal and preparing it for market:— It is estimated that as the result of the coal mining of the last fifty years not more than 30 per cent. of the coal remaining in the veins worked has on the average been won and laid down at the point of consumption or use. This loss of 70 per cent. does not of course include the loss due to geological causes, and especially to erosive agencies that have cut so deeply and so wastefully into the coal originally deposited in the coal fields. So great is this geological waste that Professor Lesley estimates that not over 1 per cent. of the coal originally deposited in the great Pittsburg bed still remains, and yet he declares this bed, robbed as it has been, to be the most valuable deposit of coal in the world. In the later years of this half century the waste has not been so great; but when all things are considered the estimated loss in mining of 70 per cent. of the coal remaining in the strata is not excessive.

As to the causes of this waste and the methods by which it may be reduced but little remains to be said, at least so far as relates to anthracite coal in the United States since the publication of the Report of the Pennsylvania Commissioners on Waste of Coal Mining, of which commission Eckley B. Coxe was chairman. Mr. Coxe points out that there are two classes of waste in coal mining:—

1. That which is absolutely necessary and cannot be avoided.
2. That which may be diminished or done away with.

The unavoidable waste is defined to be that portion of the coal that must be

left in the mine for various purposes. It does not follow, however, that what is to-day termed unavoidable waste is absolutely unavoidable. It may be, with our present knowledge, but what this term "unavoidable waste," really means, in many cases, is simply that under present conditions, or under the engineering adopted, it is regarded as most economical to leave this coal in the mine. It is left to maintain the workings, the slopes, shafts, gangways, etc., to support the surface, to make the floor and roof, to keep the water from the lower levels and save the expense of pumping; in a word, to keep the mine safe, and in a condition that it can be worked economically. Conditions, appliances, and methods, may so change, beyond question will so change, that what is economical to-day, may be most wasteful to-morrow. The history of mining shows this.

Just what is the loss from this so-called unavoidable waste in mining at the present time is difficult to ascertain. In some instances, it is not 10 per cent.; in others, as high as 50 per cent., or more. This refers to the veins actually worked and to those portions that are worked, and not to those that are in whole or in part regarded as not workable. If this unavoidable waste average 20 per cent. of the amount of coal left, the loss from this source in the United States, in 1893, was 36,470,555 net tons, and on the production of Great Britain, in 1894, it was 42,174,166 net tons. If the waste for fifty years is considered, the amount will be enormous.

This unavoidable waste can be reduced. It is being reduced as the results of the application of engineering skill. When the day comes that the near exhaustion of coal will be a thing of to-morrow, and not of a century, it will be found that a waste that is now called unavoidable will then be termed criminal. As to the avoidable waste in mining. This is largely due to:—

1. Miscalculations as to the amount of coal that must be left for the pillars, etc.

2. The leaving of large amounts of coal unmined in a vein.

3. Imperfect work on the part of the miner.

The loss of coal from miscalculations or bad engineering of the mine is enormous. Pillars may be too large and the coal wasted; or, too small, and the pillars crush and shut off the coal beyond. It is not unusual to leave unmined a part of a vein that is either under or above a slate, and which may not be quite so pure as that mined. The waste from this source is enormous. There are mines in the Pittsburg region where, with seventy-one and one-half inches of coal, but thirty-two inches of clean coal and the bearing-in coal of four inches are mined; thirty-six inches out of seventy-one and one-half inches are left untouched, a loss of thirty-five and one-half inches; practically, one-half of the coal is left in the mine, besides the waste in mining. This custom is not at all uncommon. The miner may do his work very unskilfully in bringing down the coal, in loading and other ways to which I need but refer at this time. How can this waste be avoided?

It cannot be entirely avoided, but it can be still further decreased by just the methods by which it has already been largely reduced. Mechanical means, instead of the coal itself, can be used for supporting the roof and surface; gobbing up will often give a much larger percentage of coal; better engineering of the collieries will give better methods and less waste. All of the vein can be mined, even if a portion of it is inferior, and many methods can be greatly improved.

Secondly, as to the problems connected with the use of coal. It is estimated that not to exceed ten per cent. of the possible energy in coal is utilised; indeed, 5 per cent. is the amount most frequently named. Some of this loss is unavoidable, and will ever be so until we have solved that greatest of all modern industrial problems, how to obtain energy direct from coal. But much of this waste is avoidable, and to reduce this avoidable waste is the fuel problem in connection with the use of coal.

What has been done in reducing this

waste in the last 100 years is simply astonishing, and what is of especial interest is that many of the improvements and processes that have been introduced into the arts within this time have been the results of attempts to diminish this waste of fuel. The story of many of these inventions, could they have been told by a Stevenson, would have given us new Arabian Nights tales more marvellous than those he did tell. What marvels have been performed by the genii Watt unloosed from the boiling kettle! The gas Murdoch told men how to use is a veritable Aladdin's lamp, and the stories of the wonders of Neilson's hot blast and Bessemer's fiery converter and Siemen's furnace of the heat cycle and many others are marvellous beyond belief.

Fuel in the arts has at least a threefold use. 1. As a simple heat agent. 2. As an agent of chemical changes. 3. As a source of power or better energy.

We have no complete estimate of the consumption of coal for various purposes in the United States, but the royal coal commission, in 1871, and Mr. Price Williams, in 1889, made very careful estimates of the distribution of coal consumption for Great Britain. I had hoped to have obtained an approximate estimate of the consumption of coal for various purposes in the United States, but so far have failed. The estimate of the royal commission is as follows:—

Consumption of Coal for Different Purposes in Great Britain—Coal Commission Estimate, 1871—Tons of 2240 Pounds.

Uses.	Tons.
Iron	32,446,606
Power and general manufacturing	23,327,213
Domestic	18,481,527
Gas and water	7,811,980
Mining and collieries	7,225,423
Steam	3,277,562
Railroads	2,027,500
Smelting other than iron	859,231
Miscellaneous	195,045
	97,652,087

Percentages for Various Uses.

	Per Cent.
Metals and mines	44
Domestic, including gas and water	26
General manufacturing	25
Locomotion by land and sea	5

Consumption of Coal for Different Purposes in Great Britain—Williams' Estimate, 1889.

	Per Cent.
Production of steam power, including collieries	30.30
Manufacture of pig-iron and metallurgy	17.26
Navigation	8.66
Railways, including fixed engines	3.98
Water-works and miscellaneous	1.40
Domestic use	17.44
Export	15.09
	100.00

It is impossible at this time to distribute this consumption even approximately into the three uses, heating, chemical and power, but it will be seen readily that by far the larger consumption is for power and in iron manufacture. It would seem from an inspection of these two estimates that from 60 to 70 per cent. of the coal consumed is for power, and for iron and steel manufacture.

What economies have been wrought in these industries in the past 100 or 150 years?

In engines since the days of the Newcomen engine the duty of 94 pounds of coal has increased from 7,450,000 foot-pounds to 140,000,000 foot-pounds,—the highest duty of Mr. Leavitt's pumping engine at Louisville,—and the pounds of coal per indicated horse-power decreased from 26.6 pounds to 1.33 pounds, an increase in duty of twenty times, and a reduction in coal, of course, of one-twentieth.

The following table shows what has been done in detail:—

Duty of Cornish Engines.

	Duty in Foot-Pounds per Bushel (94 Pounds) of Coal.	Pounds of Coal per I. H. P. (Estimated).
Newcomen	7,000,000	26.6
Smeaton	10,000,000	18.6
Watt, 1800	20,000,000	9.3
Lean's report, 1815	52,300,000	3.6
Lean's report, 1827	67,000,000	2.8
Lean's report, 1834	98,000,000	1.9
Lean's report, 1840	107,000,000	1.7

Highest duty of Mr. Leavitt's pumping engine at Louisville, 140,000,000 per 100 pounds of Pocahontas coal. Pounds of coal per indicated horse-power, 1.33.

As to the reduction of waste in iron and steel manufacture, I need only mention Neilson's hot-blast, the Bessemer or pneumatic process, the Siemen's regenerator. One example of the reduction in the use of coal in iron manufacture must suffice. In 1828 Neilson

invented the hot-blast, which Mushet said "ranks with the invention of cotton spinning." At the Clyde Iron Works in 1829 for a six months' run the average coal consumption per ton of pig with cold-blast was 8 tons, 1 hundredweight, 1 quarter; for six months in 1830 at the same furnace with the same blowing engine the consumption with hot-blast was 2 tons, 5 hundredweight, 1 quarter. To-day we are making pig-iron with a ton of coke, or 1½ tons of coal to a ton of pig. This indicates what has been done in the arts in reducing fuel consumption.

But modern practice has not reached the limits of economy. If we get but 10 per cent. of the available energy out of our coal there must be a vast field for the exercise of engineering skill in reducing this enormous waste of 90 per cent. Sir William Armstrong states that without carrying economy to extreme limits all the effects now realised from the use of coal could be obtained by an expenditure of half the quantity.

In what direction are we to seek for the answers to the problems connected with the use of coal? I can only briefly indicate them. They are:—

1. A more perfect combustion; that is, from the same amount of fuel more heat units must be developed.

2. Improved appliances for saving this heat and transmuting it into energy. Not only must these increased heat units do more work, but each individual heat unit must directly develop more energy.

3. Recuperation of so-called exhausted energy; that is, the heat must continue at work until the actual limit of exhaustion has been reached.

The use of gases instead of solid fuel is an example of the first direction in which we are to look for the answers to the problems connected with the use of coal. The improvements in the steam engine noted above are examples of the second class, and the Siemen's regenerator and compound engines of the third.

Thirdly. The saving of fuel products other than heat.

As has been pointed out, it is as a source of heat and power that fuel, that is coal, is most useful to the world. But it has been learned that there is locked up in this fuel a marvellous series of products which for their beauty, their wonder, their sweetness, their use, are unexcelled, and the end of the story of these products is not yet.

To indicate what these products are, I need but name the brilliant coal tar dyes, those contributions of untold value to the healing art as phenacetin and antipyrine, many of the modern perfumes and essences, and saccharine, sweeter than cane sugar.

While the discovery and character of these products are the fairy tales of science, and while the products themselves are of untold value to mankind, there are fuel products other than heat and power and other than these coal tar products that in amount and value far exceed these dyes and medicines and perfumes. The chief of these are the tars themselves from which are derived the light and heavy oils, the creosotes and benzoles, the ammonia from which we get that most valuable of all fertilisers, sulphate of ammonia, upon which the exhausted fields of the country must depend for their renewal of power. From the nitrogen of this fuel, we may also obtain that most poisonous of drugs and yet that valuable agent in gold extraction, cyanide of potassium.

The amount of these products contained in every ton of coal and the consequent amount that we are every year throwing into the air as waste, aggregates an amount almost beyond belief. In every ton of coal coked in the United States, it is fair to assume that from any of the by-product coke ovens, there can be produced at least 3 per cent. of tar worth one-third of a cent per pound; 1 per cent. of sulphate of ammonia worth 3 cents a pound; one-half of 1 per cent. of benzole worth 2 cents a pound, and one pound cyanide of potassium worth 50 cents per pound. As in 1893, 14,916,147 tons of coal were coked in the United States, the possible production and value at present prices

of these products would have been as follows:—

Materials.	Amount, Pounds.	Value,
Tar	596,645,880	$1,988,820
Sulphate of ammonia	298,322,940	8,949,688
Benzole	149,161,470	2,983,229
Cyanide of potassium	14,916,147	7,458,073
		$21,379,810

The above products, however, are only those from the 15,000,000 of tons of coal coked in one year. What about the value of the by-products of the 113,000,000 tons of coal not coked? How many tons of tar and ammonia and benzole and cyanide could be saved from this amount of coal? The amount of ammonia would be something enormous, though the tar and benzole, if the coal was properly burned into gas before it was applied to heating purposes as it should be, would not be so great as when the coal is coked. The Mond circular producer, which I saw at work a year ago in England on Yorkshire coal, gave 48 kilos (105 pounds) of sulphate of ammonia per ton of coal charged, and 80 to 90 pounds was the regular yield.

Let us recapitulate. Of the coal still remaining in the seams worked, not more than 30 per cent. on the average in the last fifty years has been won; that is, 70 per cent. has been lost.

The percentage of the possible energy of coal utilised to-day does not exceed 10 per cent. if it reaches 5 per cent.; that is, but 10 per cent. of the 30 per cent. of the coal won in our veins, or but 3 per cent. of the possible energy imprisoned in the coal in our hills is ever released for useful work.

The value of this lost energy must every year, in the United States alone, reach hundreds of millions of dollars.

A low estimate of the value of by-products per ton of coal burned would be 50 cents. This would be $64,000,000 on the coal mined in 1893. For an age that prates so loudly of its economics, this is a sorry showing.

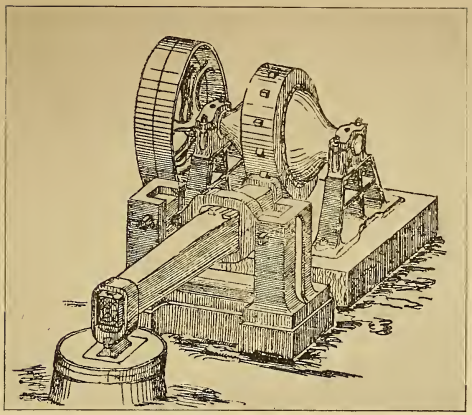
Is there not in this fuel question a problem that demands most earnest work from engineers, and in which there is for the miner and manufacturer untold wealth?

THE USE OF POWER HAMMERS.

By G. H. Scranton.

POWER hammers are to-day occupying a very important position in the list of tools required for the production of work in an economical manner, and also where a superior quality of forging is desired. They are known under several names, such as trip hammers, helve hammers, dead stroke hammers, spring hammers, etc., but the general term power hammer is given to all quick-stroke hammers, run by a belt direct from a shaft, to define them from those run by any other means, such as steam, compressed air or electricity.

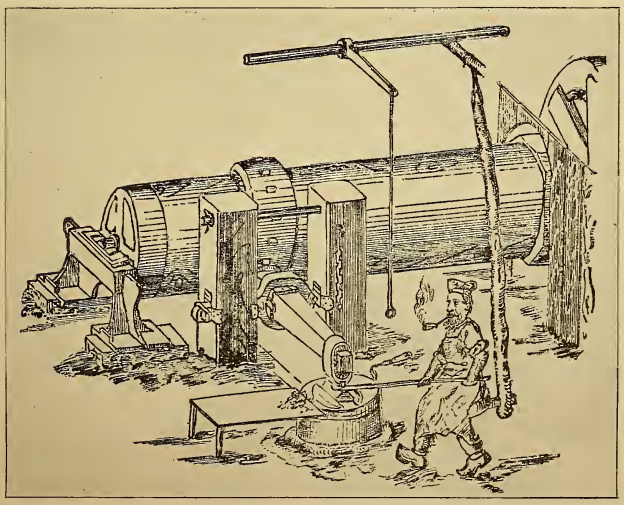
For over twenty-five years mechanics have been improving the design and construction, until to-day hammers manufactured even ten years ago cannot find a place in a well equipped forge shop, although hammers of ancient design may occasionally be found still running in some out-of-the-way place where the proprietors have failed to avail themselves of the opportunity to economise, either from lack of capital or enterprise. The illustration on the opposite page will give an idea of the manner in which workers of metals in olden times may have constructed a hammer, and hammers can be found even now which do not differ materially in principle from this. There are many manufacturers to-day, who could greatly reduce the



AN OLD-TIME POWER HAMMER.

cost of their production were they familiar with the results to be derived from the proper use of a power hammer, and it is to these particularly that this brief article is addressed.

In file work the power hammer is the only tool which has proved satisfactory for tapering and tanging the blanks as the file is not only formed into the proper shape, ready for grinding, but the material is greatly improved by the hammering. The same may be said of



ANOTHER FORM OF ANCIENT DATE.

the manufacture of knife blades, chisels, and all classes of tools into which the refining of the stock enters as an essential feature.

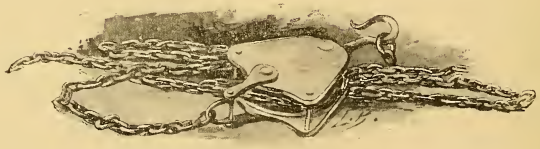
For ordinary forging where it is required only to form the stock into certain shapes, a power hammer is absolutely necessary, especially where many pieces of the same shape are needed. The hammer will not only produce the work much more rapidly, but much more uniform in shape, thus saving expense in labour, fuel and the machining after it is forged. In this class may be numbered manufacturers of carriage irons, bicycle forgings, bicycle tubing, agricultural implements, bridges and structural iron work, machinery, firearms and the like.

A power hammer is of great value as an auxiliary to a drop hammer in forming the metal into proper shape to be placed into the drop dies by drawing or flattening a certain part which, if done entirely in the drop, would require an extra heat, another set of drop dies, and much more time.

It is the aim of manufacturers of power hammers to produce a rapid, accurate and heavy blow with as small an expenditure of power as possible, and to so construct the machine that the concussion, caused by the dies coming together, will not granulate the part or cause the metal to break. The strain created by this concussion is great, and it is, therefore, requisite that the material should be the most suitable for the purpose, and the workmanship first-class in every respect. It has been noticed repeatedly that work coming from the forge shop to the grinding or milling machines varied perceptibly in its dimensions. This represents not only cost of extra labour in reducing it to desired gauges, but also a waste of stock, and is a fault which could be eliminated by the use of suitable dies in a power hammer. Bicycle work is a good illustration of this, as the quality and uniformity of the work are primary features with which the manufacturer has to contend, and imperfection in either is fatal.

The hammering of the more precious metals after they have been formed into bars, will reduce the possibility of their cracking under heat, which is so distressing to the smith. A hammer may be used to advantage in pointing tubing so that the workman may grasp it with his tongs and the reduced points enable him to start it in the rolls.

Not an unimportant line in which the power hammer is used is that of beating gold, silver and aluminium into sheets, as a quick uniform stroke is obtained, of much greater force than is possible for a man to exert with his arm, and with less injury to the moulds.



ELECTRIC FIRE PUMPS FOR MILLS.

By Charles L. Newcomb, M. E.

THE independent protection of mill property from the ravages of fire has always held a prominent place in the consideration of fire risks. This interest is due first, probably, to the great value represented in the extensive structures and the expensive machinery contained in them; second, to the danger of fire being generated by the machinery or by various necessary supplies; third, because, often from considerations of shipping facilities or power, the location is distant from a public fire department; fourth, there is usually such an abundant supply of power that great reliance may be placed upon it to assist, if not to supplant, all other protection.

Partly from the individual interest of owners, and more prominently from their combined interest, as represented by mutual mill insurance companies, rapid strides have been made in adopting new fire fighting appliances and a stimulus has been given to the perfecting of such devices. But this is not the age in which to say that for this reason a resting place has been reached. A system may be pronounced excellent and the best thing possible simply because it is the best that has yet been found. But it is liable at any time to be made second best and, therefore, open to criticism by the advent of some new discovery.

A good power pump, connected with the mill shafting, affords a certain amount of protection. The possibility that this shafting may be disabled by fire, creates a demand for a steam pump in its place or as an auxiliary. A steam pump in a separate building was suggested in order to lessen the probability that the machine itself might fall an early victim to the fire. To hold a supply of water in reserve, if the pumps should fail to start or should stop working, the elevated tank was provided. Certainly, independent pumps, isolated pump buildings and storage tanks were advances, but the pump still depended for its power upon a steam plant located in the mill. In fact, fires frequently originate in the boiler room, and the boilers are almost immediately disabled.

The risk due to delays in discovering the fire and in the starting of the pumps was lessened by the application of the automatic sprinkler system. To the isolated steam pump has also been added, in due time, an independent quick-steaming boiler. But in the various plans thus briefly outlined there are obvious weaknesses. The automatic supply is of limited duration, and all other forces, thus far examined, require personal attention and more or less time in their application.

What might be termed an ideal plant would be a pump of ample capacity, located at a safe distance from the mill, capable of starting automatically, and driven by a power entirely independent of the mill. Much of this has remained as an ideal only, until the rapid extension of electric lighting and electric power brought an ideal power practically within the reach of all. The steps necessary to apply this recent acquisition to the fire protection system of a mill are few and simple, and it seems most fitting that the mysterious current which has been charged with setting many fires, should now be compelled to assist in their subjugation.

The elements entering into the combination which will transform the energy of the electric current, taken from some convenient line, into an abundant, persistent current of water through the piping of a mill are these :—An electric

motor, connected through a suitable switch with the electric line; a power pump, connected with the motor; a sprinkler system, connected with the pump; and a pressure regulator in connection with the pipe system, and controlling the movements of the electric switch. All these parts, except the piping, may be placed in a suitable building at a safe distance from the mill.

Under normal conditions all outlets in the pipe system are closed; the pipes are filled with water under a given pressure, determined by the setting of the regulator; this regulator holds the electric switch open, and the motor and the pump are at rest. Upon the starting of a fire, one or more sprinkler heads open under the influence of the heat, the water pressure falls slightly, the regulator responds to this change, closes the switch, starts the motor and pump, and the necessary water supply is maintained. Any excess of supply over demand will at once raise the pressure, act upon the regulator and stop the pump. Slight fluctuations in pressure may be compensated for by connecting an ordinary pressure tank with the pipe system.

In addition to the pipe connections upon the pump there may be suitable hose fittings from which direct fire streams may be taken when required. Small demands upon the pump will be met by its starting and stopping at intervals, while the use of more openings may require its continuous action. It is evident that the ordinary, as well as the fire, supply may be drawn from this source.

The various parts in this electric pumping plant are all of simple construction. No untried principle is involved. There is no expensive delay in the early movements of the fire, and nothing is left for adjustment during the excitement.

That there are more separate elements in the automatic electric plant than in the appliances which have preceded it does not necessarily imply that there is greater complication. If the complication were greater, it might well be justified on the ground that it accomplished much greater results. But the increase in elements seems to be somewhat on the principle that a faucet has more parts than a bung. It is also a better device, as it contains, in itself, both the bung and the bung-hole and convenient means of connecting the two. The electric fire pump is not only bung and bung-hole, but an inexhaustible barrel as well.

The electric supply can now be so easily obtained, it can be so readily applied for power purposes and the new features can be so cheaply added to existing systems, that unquestionably the advances which electricity has brought in modes of communication, travel and lighting, must be soon followed by corresponding improvements in methods of fire protection.

CHARLES FRANCIS BRUSH.

IT was of Mr. Brush that Gambetta remarked, as he saw the commanding figure of the great American inventor at the Paris Exposition in 1881, "I do not know which to admire most,—his extraordinary mental talents or his magnificent physique,"—a remark suggestive alike of his splendid achievements in the field of applied electricity and of his striking personality.

Mr. Brush may justly be considered the father of the electric arc lighting industry of the world,—an industry in which there are now invested many hundred millions of dollars,—but in other branches of electricity his name has become quite as well known. A

tireless spirit of industry and a special bent toward physical and chemical investigations have kept him for years engrossed in labours that have resulted in pecuniary and scientific profit of a decided character.

Mr. Brush was born in 1849 near the city of Cleveland, in Ohio, and in 1864 he entered the Cleveland High School from which he graduated with high honours three years later. During all this time he was busy with experiments in mechanical devices of all kinds. Even at this early date his attention was directed to electrical phenomena and it is a peculiar thing that during his high school days one of his first inventions was a device for turning gas on the street lamps, lighting it and then turning it off again by electricity. He also became greatly interested in photographic experiments and was among the first to do dry plate work, until then an almost unknown process. Chemistry was, however, his chief delight, and he made rapid strides in this branch of science. During his senior year, the physical and chemical apparatus of the school having been placed entirely under young Brush's charge, he produced his first electric arc light with a lamp and battery of his own construction.

The subject of his graduating oration was "The Conservation of Force," in which the young inventor traced the chemical energy of the sun's light through the vegetation of the carboniferous period to the coal subsequently formed therefrom, thence to the heat of combustion in the furnace of the steam boiler, thence to mechanical power and the electric current produced thereby and finally the evolution of the electric light.

Mr. Brush next entered the University of Michigan, where, in 1869, he was graduated with the degree of mining engineer, one year in advance of the rest of his class. He then returned to Cleveland and organised a laboratory, where for three years he conducted the business of an analytical and consulting chemist.

In the spring of 1873 Mr. Brush formed a partnership with C. E. Bingham for the purpose of handling and marketing iron and iron ore. He still continued his electrical investigations, however, and in 1876 completed his first dynamo electric machine. This machine was of a distinctly new type and marked the first of a long series of brilliant inventions which have made Mr. Brush's name famous throughout the world.

In 1877 Mr. Brush withdrew from his partnership with Mr. Bingham and thereafter devoted his entire attention to electrical invention. He also made a contract at that time with the Telegraph Supply Company, of Cleveland, by the terms of which that company undertook the manufacture and sale of his inventions, paying him a royalty on all apparatus thus made. In 1881 the name of the company was changed to the Brush Electric Company, with largely increased capital. Early in 1877 Mr. Brush invented and constructed his first commercial arc lamp, which was exhibited with one of his new dynamos at the Franklin Institute at Philadelphia, where both pieces of apparatus carried off all the honours against the best known lamps and dynamos of that period.

But it was his invention of the famous series arc lamp having a regulating shunt circuit of high resistance which first made commercial arc lighting from central stations possible. On this invention are based all the arc light system in use throughout the world.

Among Mr. Brush's other inventions of early date may be mentioned his copper-plated carbons for arc lights, many millions of which are now used monthly; his automatic cut-out for arc lamps, now universally used in various forms, and almost indispensable; his compound series-shunt winding for dynamo-electric machines, now very generally used for lighting by incandescence, and in power transmission, and his multiple carbon arc lamp for all night burning.

It has long been the rule that the genius which conceived the great inventions for the amelioration and improvement of human needs have been

but lightly rewarded. Mr. Brush is fortunately an exception to this rule, and while the laxity of American patent laws has worked against him as against nearly all the great inventors of the country, he has been fortunate in the sale of patents abroad. In 1880 he sold many of his early patents to a London company, formed for the purpose of exploiting them and known as the Anglo-American Brush Electric Light Corporation, Limited, from which he received emoluments amounting to about $500,000—a price for patents at that time almost unprecedented. From that time Mr. Brush's wealth rapidly increased until he has become one of the wealthiest as well as one of the most distinguished of Cleveland's citizens.

Success has crowned all the efforts of this thoroughly typical American. His researches have enriched and benefited the entire civilised world and it is a pleasure to record that he has reached both honour and pecuniary reward.

Mr. Brush is a member of many engineering societies. At his graduation the University of Michigan conferred upon him the degree of M.E.; in 1880 the Western Reserve University invested him with the degree of Ph.D.; and in 1881, in connection with the Electrical Exposition held in Paris, the French government, in honour of his distinguished inventions and contributions to the world of science, decorated him Chevalier of the Legion of Honour.

THE STORAGE BATTERY FOR CENTRAL STATIONS.*

By Arthur E. Childs.

THE object of this paper is to bring before the Institute the main facts and considerations concerning the application of accumulators in electric generating stations both for light and power. The fact that storage batteries have reached a point of high efficiency and low cost of maintenance has stirred up engineers in the United States to consider the application of storage batteries to their own plants, and thus the accumulator has assumed great importance at the present time, especially as power and light stations are so far developed that further increase in generating capacity means large additional expenditure, and in a great many cases the rebuilding of the entire plant.

Realising, therefore, that storage batteries are eminently practical as auxiliaries, and that their utility and value are acknowledged throughout Europe, it is not surprising that engineers and managers in the United States are inquiring about them with the end in view of securing the full measure of their advantages and benefits. In England and on the Continent, storage batteries have been used in central stations for more than five years, and the success of their application has brought about a great change of feeling regarding them, and the respect with which they are now regarded is an ample indication of the value they have been to managers in the operation of their stations.

It is an acknowledged fact that the great variations and fluctuations of the load on power circuits, especially those power circuits supplying trolley lines, are among the greatest difficulties which engineers have to contend against, and any appliances which will aid them to arrive at a satisfactory running of their station is looked upon with favour by them. It is only in the ranks of those short-sighted engineers, where ignorance and prejudice are the rule rather than the exception, that there are found men who will refuse to consider the storage battery as an auxiliary.

In this paper the term "variation"

* From a paper read before the American Institute of Electrical Engineers.

is used to designate the change of current induced by the adding of lights on to a lighting station, or the cars or motors on to a power station. The term "fluctuation" is used to indicate those rapid and necessary changes of current taking place on the outside line, due to stopping or starting of cars or throwing on or off of stationary motors. Although they may be thus differentiated, they bear a certain relation to each other, and in applying a storage battery, a study of the conditions will quickly indicate the type of battery which will be more favourable in each case. By the "type" of battery is meant the slow discharge battery for a long period of service, or the rapid discharge battery for a few hours, or even less time of discharge.

In the lighting station, if we bear in mind the usual form of curve, it will be remembered that the instantaneous changes of current are minute and almost imperceptible compared with the steady increase or diminution of the total current of the station. Comparing the lighting curve with the usual form of power station curve, it will be noticed that the instantaneous changes of current are enormous compared with that in the lighting station curve. There is a similarity in the two curves in the fact that at certain hours of the day more cars are operated than at other hours, thus producing a general rise in the level of the power curve corresponding to throwing on of a number of lights in the lighting curve.

It is not the purpose of this paper to discuss the characteristics of the two curves, but to consider in a general way the application of storage batteries to the wiping out of the fluctuations and variations as they come upon the dynamos and engines. The introduction of a storage battery into a central station acts in a certain sense as a buffer between the external load and the dynamos, taking the shock of the variations without throwing the same on the engines. In this regard they have the effect of reducing the average percentage variation in load on the dynamo from a large amount to a very small one, making the operation of the machines more efficient. In fact, a storage battery acts as a regulator in this instance, maintaining, as it does, a constant voltage at the switchboard. This introduces the question of the efficiency of engines with varying loads; and, leaving out of account the reports by engine builders, who are naturally interested parties, it is a fact that not many extended and careful investigations of efficiency under varying loads have been carried out. Professor W. C. Unwin, of the Central Institution, at South Kensington, has shown, however, that a decrease of mechanical efficiency has a serious effect on the economy of working with a variable load, and with a load varying from 100 per cent. to 25 per cent., the efficiency decreases from 85 per cent. to 40 per cent.

As applied to power stations, and especially where water power is used, storage batteries are almost indispensable. The writer knows of several plants where the successful maintenance of a constant voltage on the machines is dependent upon the fact that an attendant sits by the governors of the wheels, and regulates them by hand, as the inertia of the water, even when the best water-wheel governor that has ever been produced is employed, is too great to allow the turbines to pick up or throw off the load with anything like the quickness with which it is thrown on or off by the outside circuit. The stations in mind are not small stations, as might be supposed at first thought, but are stations where several thousand horse-power and over are generated at certain hours of the day; and it is surprising that engineers of intelligence, who are usually quick to perceive the advantages of new applications, are still allowing their prejudices to prevent them from investigating the merits and value of accumulators as regulating governors in their stations.

In the application of storage batteries to the power station of a trolley system, it is not unusual to find the variation in load as much as fifty per cent. below

the average horse-power, and even as great as 200 per cent. above the mean load. These enormous fluctuations take place in the course of a few minutes, and are an expense to the railroad companies in at least three ways. In the first instance, they require the use of a dynamo capacity very much in excess of that required where the station is operated at a constant load. In the second instance, these fluctuations reduce the life of the machinery of the station, producing a very large depreciation account. In the third instance, the efficiency of the generating plant is very much reduced, as pointed out in a previous paragraph. It has been figured out in a number of instances that could the steam be utilised in a proper manner in the engine driving the dynamos, at least 40 per cent. more work could be obtained from it.

When considering the application of storage batteries to illuminating plants, it is found that their value is equally as great as in the case of power stations, as the charging of the battery can be done while the plant is operating at light loads, thus making use of the power of their machines to great advantage. At the period of heavy load, the battery is able to take care of the peak of the load, and also to operate the lights during that period of the 24 hours when few lights are being supplied from the station.

The value of an accumulator plant attached to an illuminating station has been thoroughly demonstrated by the New York Edison Illuminating Company, and the Edison Illuminating Company, of Boston, and recently in the plant of the Lawrence Gas Company, Lawrence, Mass. In the latter case the battery is used in connection with their Edison three-wire system, and is used in the regular way of carrying the peak of the load during the busy hours of lighting. A secondary use of this particular battery is that at noon, when the large mills on the Merrimac at Lawrence shut down, they back up the water into the river above and entirely cut off the supply to the wheels of the gas company (for some 25 or 30 minutes), which are thus unable to operate the machines furnishing light and power until the overflow of the water, which is dammed back, comes down and allows the station to be operated. This short period of absence of water is taken care of by the storage battery plant.

The storage battery can also be used as a valuable adjunct to both power and lighting stations at points in their systems where it is difficult to maintain the voltage at periods of heavy load. In these cases the feeders are usually not sufficient to carry the whole current direct from the station. But during the periods of small load the feeders can be utilised up to their maximum allowable drop in potential to charge battery sub-stations placed at these weak points. When the load at such points becomes greater than the capacity of the feeder, the battery comes into play and carries the load in connection with the station supply at that point, thus maintaining the voltage and doing satisfactory and valuable service. There must be hundreds of street railroads in existence that have just such weak points, and the expectations of those interested in storage batteries would not be exceeded if half the street railroads and direct current lighting plants in the United States and Canada should adopt, within the next few years, storage batteries either at their central stations or at sub-stations, the more especially as they can now obtain storage batteries which are thoroughly reliable, and which can be installed under a guarantee.

The extent to which storage batteries have been used in England and on the Continent is very great, and it will surprise many engineers in America to know that there are more than 20 lighting stations and several thousand isolated plants in Great Britain alone, using storage batteries. Further than this, there are in Germany 5000 isolated plants and 15 railway power plants using storage batteries. In fact, 80 per cent. of all the central stations in Germany and Austria are equipped with storage batteries. In addition to

the above, there are many stations in France, Italy, Holland, Belgium, Sweden, Norway, Denmark and Spain, and two or three in Switzerland.

A survey of the progress which storage batteries have made in European countries, indicates no very great change in the principles of construction, but the results seem to be rather due to a thorough analysis and appreciation of the requirements of each case. This has resulted in a proper use of batteries and a correct recognition of the limitations of their usefulness. This fact alone has contributed largely to their successful application. The great difficulty in the United States has been that engineers have not recognised a proper limit to the usefulness of a battery, but have, in many cases, far exceeded their specified limitations, and in this way have injured the batteries and cast discredit on them. It would be just as reasonable to overwork an engine until injured or worn out, and then declare that all engines were useless and expensive mechanical contrivances.

One point which has contributed largely toward the success of storage batteries in Europe, is the fact that engineers have endeavoured to obtain long life and high efficiency even at the expense of increased first cost, and instead of attempting to obtain a large output per pound of element, they have limited themselves to a reasonable number of ampère-hours per pound.

The result of this has been that the batteries in use in Europe have shown great endurance and solidity. The experience, however, which has been obtained with many American batteries has not been so promising as on the Continent owing to the lack of proper appreciation of them. It would be greatly to the advantage of American engineers if they would follow the lines laid down by their European *confrères;* and if, instead of waiting for some marvellous development in the manufacture of storage batteries, they should make use of the existing high-class and efficient batteries which are now offered to the public, and use them in a reasonable manner, they would obtain valuable and even remarkable results.

Great progress has recently been made in manufacturing large batteries which have a capacity enough to take care of the needs of central lighting and power stations, and engineers need no longer complain that they are unable to get the large cells which they require. In fact, manufacturers can produce cells having almost any given capacity.

Considering the efficiency of a storage battery, the factors which tend to reduce it are due to a loss in voltage and in the quantity of current. These losses, however, are not so serious as they have been in the past, and manufacturers are at present able to guarantee a very high efficiency. In cells which were submitted to Professor H. L. Callender, an ampère efficiency of 96.1 per cent. was recorded, the watt efficiency being 84 per cent. In certain instances, however, known to the writer, these efficiencies have been slightly exceeded, and complaints from central station managers that they cannot obtain efficient cells are now groundless, as with the efficiencies named an eminently satisfactory service can be obtained. It must be borne in mind that a loss of 16 per cent., or even 20 per cent., in the efficiency of the battery does not mean the loss of the same percentage in the output of the station, as the battery usually supplies, approximately, or even less, of the whole output in watt-hours, and it is, therefore, from that fraction of the whole output that the loss in the battery must be deducted.

In the matter of cost of maintenance of a storage battery outfit, it is now usual for the manufacturer to guarantee a fixed annual percentage. This percentage varies from 10 per cent. in small plants to a smaller percentage in large plants, depending, of course, on the conditions of operation and the use to be made of the battery, a study of which will soon determine what percentage can be guaranteed. In first-class plants, well installed and operated by careful engineers, the cost of maintenance can be reduced to the vicinity of 3.5 or 4 per cent.

It is customary for the manufacturers to enter into a contract in the case of large plants, guaranteeing that the cost of maintenance shall not exceed a certain percentage per annum for the period of contract. This can be carried out in two ways. Either the lighting or railroad company can pay the manufacturer the percentage specified every year, and the manufacturer will inspect and keep the battery in first-class condition; or the company employing the batteries can inspect and order renewals themselves, in which case, should the cost of maintenance exceed the percentage guaranteed, the manufacturer will not charge more than the specified amount.

This is an exception rather than the rule, however, as the cost of maintenance is usually somewhat lower than that specified by the manufacturers, so that the company owning the battery is the gainer by the difference in percentage. By a thorough attention to details, both large and small, the percentage can be kept down to a very low figure, and it is to be regretted that the practice of engineers which prevails in Europe, of treating the battery with care and consideration, does not seem to exist among the engineers of America, to the detriment of their own lighting or railroad plants.

It must not be assumed from the above that storage batteries require an inordinate amount of care and trouble. On the contrary, they do not require either expense or great care. All that is demanded is regular and systematic attention on the part of those having them in charge. When such care is exercised, it is found that batteries perform a very valuable service, and largely reduce the operating expenses of the station—in many cases as much as 30 to 35 per cent. This reduction in operating expenses is, of course, due to the saving in cost of coal consumed, a saving which could not otherwise be obtained.

Where water power is employed, a storage battery enables the water-wheels to be operated for twenty-four hours, storing current while the station output is reduced to a minimum, and aiding the station during the busy hours of the day. In many cases this practically doubles the output of the station without increasing the cost of installation to a corresponding amount. In fact, in many cases where water power is used, it would be impossible to double the power of a station, as there would not be enough water at hand to give double the power. This is especially true in those sections of the country where the power of small streams has been utilised and where the flow of water is continuous but not very great. In addition to a storage battery acting as a receiver for storing the current while the station is not giving a large output, it also maintains, during the operation of the station, a perfectly uniform voltage, which would not be obtained with the varying load direct upon the water-wheels, on account of the difficulty in governing previously mentioned.

When an entirely new power plant is to be built, there is no doubt that by adopting the storage battery in the first instance, the initial cost of installation will be less than for the plant not using storage batteries, and the cost of operation of the station will certainly be very much reduced when the station uses storage batteries. In the case of existing plants which have to be extended, it has been proved that a kilowatt-hour capacity can be added more cheaply to the station by the addition of storage batteries than by the addition of generating machinery, while, of course, the cost of operation is much reduced.

Referring to the primary cost of storage batteries, the cost per kilowatt hour output is relatively greater for small cells than for large ones, since the cost of manufacture is reduced per kilowatt-hour in the larger sizes, whereas the jars and tanks which are used to hold elements do not decrease very much with the decrease in size of the elements. The cost of shipment and erection are, of course, slightly less per kilowatt-hour with the larger sizes than with the smaller ones, and, on the whole, the cost per kilowatt hour with the larger cells is less than with the smaller sizes.

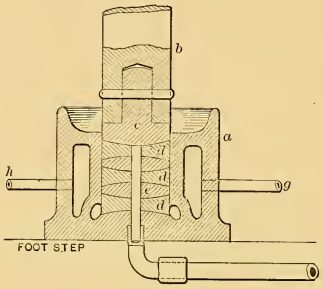
It is stated by the Electric Storage Battery Company that they are now installing large plants of the Tudor type, at a cost per kilowatt-hour of about $37 or $40, which cost, it is understood, can be reduced in the larger stations. The question of cost, however, is one which must be studied out in each case where it is proposed to install storage batteries, and a consideration of the cost of installation with the attendant reduction in operating expenses will very soon bring to the mind of purchasers the fact that it is cheaper to invest in accumulators than to invest in additional boilers, engines and dynamos.

Current Topics.

THE best way to keep a boiler clean is to put no dirty water into it. It is in this particular respect, however, that some of the feed water heaters and so-called purifiers now on the market fall very much short of their claims simply because they are not made large enough; not that they lack heating surface, but because they are not large enough in volume. A large portion of the suspended matter and of the chemically combined matter in the water, which forms boiler scale, will separate and settle if only time enough be given, and if the heater which will raise the water to 208 or 210 degrees be made large enough to allow the water to go through it very slowly, almost sluggishly, from the bottom upward, the separated carbonates and the mud will deposit themselves in the heater and will not go over into the boiler. If the heater be made with ample heating surface, but of small cubic capacity, the water will go through it at a speed sufficient to carry even what may be precipitated into the boiler. Thus, there are some heaters which will work very efficiently so far as heating is concerned, and yet very unsatisfactorily as separators of impurities. It will pay to bear this in mind.

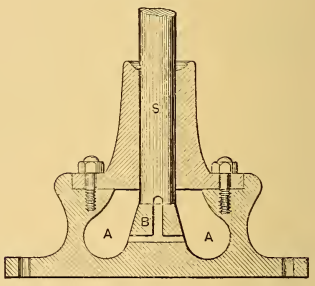
LARGE vertical shafts in mills and other buildings, for transmitting power from floor to floor, without the use of belts and the need of objectionably large openings through the floors, have of late years come into favour more and more, and with them engineers have had opportunities likewise of extending their knowledge of the difficulties which beset their satisfactory operation, that is, in so far as the step bearings are concerned. A step bearing which will run cool and wear well in the case of a

shaft of any considerable size is always an object of interest. Several years ago two such bearings were described before the American Society of Mechanical Engineers, and sketches of them have been reproduced on this page as of quite as much value now as they were then. The first of these bearings was



constructed for a large cotton mill in Lancashire, England. The mill was six or seven stories high, and, like most mills of its kind in that part of the country, was fitted up with massive gearing, an upright shaft being used with a pair of bevel gears at each floor. The shaft was 9 inches in diameter at the bottom, and came down to 5 inches at the top. Altogether the weight of the shaft and gears was very great. Several plans were tried to make a footstep that would not heat, finally the one here shown was adopted. In the sketch *a* is the base or footstep ; *b* is the vertical shaft ; *c* is a steel toe ; *d*, *d*, *d*, are bronze discs ; *e*, *e* are steel discs ; *g* is an inlet pipe, and *h* an outlet pipe for a steady flow of water through the annular space shown ; and the pipe at the bottom is a hydraulic pressure pipe communicating with pumps and an accumulator. The idea was to get hydraulic pressure on the bottom of the shaft, and to provide a stream of cold water in the annular space in the base to keep the temperature down. Whatever pressure was needed on the end of the shaft was obtained by regulating the pumps and the accumulator, the shaft being relieved from the bearing to that extent. The discs of different metals were intended to prevent the surfaces from cutting, and if one disc should cut, any one of the others could begin to operate.

In the second example, described by Mr. W. F. Durfee, the bearing and footstep were made of cast iron, with an oil well. Directly through the centre of the support *B*, on which the shaft *S* revolved, a vertical hole was drilled, intersecting a horizontal hole. On the end of the shaft *S* there was a groove, cut right across the centre. With the well *A* full of oil, and the shaft revolving, the centrifugal force tended to throw the oil out of the groove in the



end of the shaft, and the consequence was a continuous circulation of oil through the horizontal and vertical holes in the support *B* and a distribution of oil over the upper surface of that support. The arrangement was found to be very satisfactory.

Retarders or baffle-plates in the fire tubes of steam boilers have long been known as important factors in economical steam raising. The theory of their action always has been a seductive one, and with probably few exceptions it has worked out well in practice. Where the results did not come up to expectations or where, indeed, they were the reverse of what had been hoped for, it is safe to presume that some one

condition in the problem had been ignored or misinterpreted. As with many other things, indiscriminate use of retarders is not to be recommended. Primarily, the function of a device of this kind is, what its name implies, to retard something, and that something, in the case of a boiler, is the combustion gases on their way from the furnace to the chimney. The slower the passage of these gases through the boiler within certain limits, the more heat will they give up to the water in it, and the more steam will they help to make. Prolonging the time of passage of the gases implies very naturally, too, that they are made to take a roundabout path, rather than a direct one, and it is in this that some forms of retarder exercise another desirable function,—making the hot products of combustion impinge, at some points, more or less directly upon the heating surfaces, instead of permitting them to flow along, uninterruptedly in lines parallel to these surfaces. It is this breaking up of the steady stream of the gases that helps to promote the maximum utilisation of the available heat of combustion.

More recently the practical effect of retarders has been studied by Mr. Jay M. Whitham, and the results of a series of seventeen trials of a horizontal return tube boiler, both with and without retarders in its tubes, were given by him in a paper presented at the last meeting of the American Society of Mechanical Engineers. The retarders were made of loosely fitting strips of No. 10 sheet iron, running the whole length of the 20-foot tubes, and twisted to a pitch of 10 feet, or making two entire convolutions in the length of the tubes. The several tabulated statements, given in the paper, are decidedly interesting in their way and may be studied profitably from several different points of view. The particularly interesting fact in the matter of retarder influence, however, which they show is that in at least one of the tests the saving of fuel due to the use of the retarders was over 18 per cent., while the lowest recorded saving was 3.2 per cent. In two of the tests the retarders appear to have had no effect whatever. One other showing of the tables is that the retarders enable a boiler to be run as economically on 5 square feet of heating surface to the horse-power, as on 21.7 square feet, or, practically, as on any number of square feet between these limits. The general conclusions which Mr. Whitham drew from his investigations are those which, in part at least, have been held generally for many years past, but it is worth knowing that they are supported by actual test figures. He made in his deductions the statements, among others, that retarders should not be used when boilers are run very gently and when the stack draft is small; and that they may often prove to be as economical as economisers, without, in general, interposing as much resistance to the draft.

Sir John Rennie, speaking as president of the British Institution of Civil Engineers fifty years ago, said that when, by improvements in roads, carriages and horses, and by shortening the stages, the distance between London and Edinburgh was covered in forty-two hours, "animal strength and endurance had reached its utmost limits, and if any improvement was to be obtained, it was requisite to get it from a different source." He did not foresee the notable accomplishments of horses attained since that time, nor did he probably even dream of the still better performances by men on bicycles which, in the past few years, have afforded the strongest kind of evidence of animal strength and endurance. While man, however, has done much to supplement his own natural speed and power, he has done nothing in that direction for the horse In the year 1673 paddle-wheel tugs, worked by horses, were in use both on the Thames and the Tyne for towing vessels, and it is on record that between Gravesend and London they would take a ship of 1000 tons against the stream at a speed of three miles an hour. No land vehicles, similarly worked by horses

carried "on board," appear to have been ever tried; but in these days of high grade steel, roller bearings, and rubber tires, it would be interesting to ascertain experimentally whether the performance of a sturdy little Shetland or Iceland pony, carried on wheels instead of on his own legs, could not be quadrupled, as that of his weaker master certainly has been.

It is a matter of some interest to learn that in recently extending the electrical equipment of the Nantasket Beach line of the New York, New Haven & Hartford Railroad Company, in the United States, the overhead trolley system, in use on one section of the road for some time past, was abandoned and the third-rail method of contact was adopted as the most readily adaptable to ordinary railroad requirements. This seems like coming back to first principles. One of the first electric roads built, back in the early eighties, was of the three-rail type, but after somewhat protracted experimenting this arrangement gave way to the now familiar overhead wire and trolley. Its virtues, however, are now evidently better appreciated than they were in those early days of electric railroading. The third rail in the present instance is of peculiar shape, the end view resembling a flattened *A*. It is laid midway between the two service rails of each track. Each section of third rail is 30 feet long, and weighs 93 pounds to the yard. It is supported by three ash blocks to each section, the blocks being let into the ties. Before use these blocks are boiled in vacuum pans with a tar compound, and thus each pore is filled with insulating and preservative material. For continuity of the third rail circuit each end of one rail is attached to that of the next by means of two heavy copper bonds.

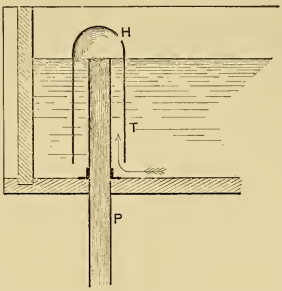
The electricity is taken from the rail by two sliding shoes, hung loosely from the car, one suspended between the axles of each truck, immediately under the king pin, by two links which allow it to slide easily over the top of the third rail and make perfect contact with it all the time. The current is brought to the motors through the controllers and circuit breakers, and returns to the track rails by the wheels. The continuity of the return circuit is secured by using a short thick bond of copper cable to join together the ends of each pair of track rails, the ends of the bond being fastened into the flange of the rail. The distance between the two shoes on the car is 33 feet. No third rail is laid at the crossings, the circuit continuing between the broken end by means of lead covered cables. At the crossings less than 30 feet wide one of the shoes is always in contact; at wider ones the impetus of the moving car brings the shoes into contact again before the car can come to rest. Should the operation of this branch road prove as successful as it now promises to be, it is likely that the three-rail system will be extended to a very considerable degree on that line.

The largest commercial electric transmission line in the world was completed a few months ago in California. It is only a little short of 35 miles and supplies light as well as power to the town of Fresno from the north fork of the San Joaquin river. The water has been led from the river through a flume and canal to a natural basin, several acres in extent, and from this basin a pipe line, 4100 feet long, is brought down the mountain side. In this distance the difference in level between the water above and that in the river below is a little over 1400 feet. At the power house the pipe enters a receiver 57 feet long by 30 inches in diameter, of ¾-inch steel, with joints of butt strap type. This receiver is designed to stand a working pressure of 800 pounds to the square inch, and both it and the water wheels are outside the main power house, the shafts passing through a heavy granite wall which effectually keeps all water and moisture out of the dynamo room. The wheels are of Pelton make, and the head of water,—1410 feet,—is the high-

est ever used for power transmission purposes.

THE electric plant consists of three General Electric three-phase generators, each of 350 kilowatts capacity, at a speed of 600 revolutions. The armatures are directly connected to the water wheels by insulated flange couplings. The current is delivered to six 125 K. W. step-up transformers wound for 11,200 volts, to which pressure the current in the transmission line is raised. This 11,200-volt circuit, consisting of six bare copper wires, after running through the 35 miles of intervening country, is brought to nine step-down transformers in the station at Fresno. Three of these are of 125 K. W. capacity and reduce the pressure to 200 volts; three are of 75 K. W. capacity with secondaries of 1000 volts, and three are of 40 K. W. capacity, reducing the pressure to 3000 volts. In addition to these transformers the station also contains two 80-light Brush arc machines, directly driven by two 60 H.-P. three-phase induction motors. The system of distribution from the sub-station is divided up into three net works. The first, a 200-volt, four-wire, low-tension net work, covers the business portion of the town and has an initial capacity of 6000 sixteen candle-power incandescent lamps. The second, a 1000 volt, three-phase system, covers the residence districts of the town and has an initial capacity of 4000 sixteen candle-power incandescent lamps. The third is a 3000 volt, three-phase circuit, designed to furnish current to the numerous vineyards and wineries within a radius of ten miles from the sub-station for both lighting and power purposes. Motors will also be furnished with current from both the 200-volt and 1000 volt systems.

IT is well known that a perforated strainer of any kind is very apt to be obstructed by objects floating in the liquid to be treated, and it may be interesting, therefore, to call attention to what may be termed a substitute for such a strainer, devised a number of years ago by Mr. W. F. Durfee, and used by him, in many instances, with good results. The device was described by him subsequently before the American Society of Mechanical Engineers and is well explained in the appended sketch. This is supposed to show a cistern through the bottom of which passes the overflow pipe *P*. In order



to prevent any substance, floating at the surface of the liquid, from going down this overflow pipe, the latter is surrounded with a tube, *T*. Anything heavier than the liquid will, of course, go to the bottom. In order to prevent the tube *T* from acting as a syphon, its hemispherical end is perforated above the level of the liquid by a small hole, *H*, or the tube may be left entirely open at its upper end. Both forms have been used with satisfaction. The flow of the liquid out of the cistern is in the direction of the arrow. In this arrangement we have a substitute for a perforated strainer, giving the full area of the overflow pipe, and which is at once simple, cheap, and thoroughly efficient.

IN a recent editorial on errors of observation, which are sure to creep into every kind of experimental work and easily nullify every possible refinement of calculation, *Engineering*, of London, has this to say :—"The amateur experimenter—and some that are not amateurs—falls a ready victim to the seduction of decimals. It is so delightfully easy to go on dividing to four, five,

six or even seven places. No sane man would dream of writing that a steam engine consumed 20 pounds, 1 ounce, $314\frac{3}{10}$ grains of coal per horse-power hour. It would be altogether too absurd. But 20.1074 pounds has an air of veracity and scientific precision about it which is irresistible to some natures. We are not guilty of burlesquing the facts in advancing such figures. Only this week we have read in an American technical paper that Captain Dewey, of the United States Navy, had officially reported to Mr. Secretary Herbert that the battleship *Massachusetts* had made on trial a speed of 16 2079 knots. Translated into ordinary measures, this means that she could cover 16 nautical miles and $1265\frac{2794}{10000}$ feet in one hour. As this is equivalent to about 27 feet a second, we may feel considerable skepticism, not only about the fraction, but also about the units, the tens, and the hundreds. The period in passing over the measured mile is so short—less than four minutes—that an error of a second or two would be material. If experimenters could cultivate a little contempt for fractions, it would prevent them giving an importance to figures that are absolutely unreliable." Every engineer knows how well founded this criticism is. Figuring down to a very small fraction of anything in engineering work, where appreciable errors of observations are more than likely to be made, is a little worse than useless.

PARIS, which has thus far been remarkably conservative in the matter of electric street car traction systems, having adopted neither overhead nor underground conduit designs, in spite of all clamour for improved transportation facilities, is now to have a closed conduit line, after a system devised by M. Vuilleumier. This is said to have been thoroughly tested in 1894 at the Lyons Exposition, presumably with satisfactory results, so that, in this instance, good performance may be reasonably expected, or at least as good performance as surface contact systems at the present time are capable of giving. At their best, they promise to be troublesome and vexatious things.

THE notion that the greater the height of a chimney for a boiler plant, the greater will be its draught producing power is responsible for the existence of many chimneys of imposing size and, at the same time, unnecessary expense. A very tall chimney, well proportioned and gracefully outlined, may be a striking architectural adjunct to a factory, but it is also one that costs considerable money without doing any measurable amount of good. Where chimneys are intended to carry off noxious fumes from chemical works, there is, of course, some method in providing for unusual height, since the aim in such a case is to insure as complete as possible a diffusion of the vapours and prevent their mingling with the air of the lower strata; but for boilers simply, unusual height, as stated, is rarely based upon a good reason.

As a matter of fact, the draught-producing capacities of chimneys, having flues of the same size, are in proportion to the square roots of their heights, so that if one were to have double the power, if it may be so called, of the other, it would have to be four times as high, and not merely twice as high as many suppose. A height of 150 feet may be considered, on good authority, as the maximum necessary in any case for producing the requisite draught, providing, of course, that the area of the flue has been properly proportioned. This latter should be made to bear a pretty nearly direct ratio to the combined areas of the boiler flues connecting with it. A chimney much beyond 150 feet is generally suggestive of misspent money.

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very Sincerely yours
Henry Bessemer.

FROM A PHOTOGRAPH TAKEN OF HIM IN 1892, AT THE AGE OF 79 YEARS.

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CASSIER'S MAGAZINE.

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SIR HENRY BESSEMER.

A BIOGRAPHICAL SKETCH.

By Dr. R. H. Thurston.

IN modern times, the fact has come to be universally recognised that the most accurate measure of the progress of a people in all the material civilising elements of advance is the quantity of iron and of steel used by them. It has been quite as explicitly admitted that the inventor is the greatest benefactor of the race and that the most beneficent inventions are those which promote the economical production of these most precious of metals. Gauged by this test, Sir Henry Bessemer may probably be fairly accorded the distinction of being classed with Tubal Cain, Hephæstus, Dud Dudley, Cort, and Huntsman, among the greatest men the world has known in this field, and it may not be claiming too much, perhaps, to say that he may fairly be assigned to the headship of that mightiest of guilds.

The present time, when Great Britain and the United States are each producing, annually, about ten millions of tons of iron, of which a large and increasing proportion is used in the form of steel, and, in that form, is finding application in every kind of construction, is peculiarly appropriate as one in which to describe his deeds and to give honour to the man who, perhaps more than any other man, living or dead, has so aided his nation and his race in its onward progress in wealth, comfort, safety and general prosperity, furnishing the material foundation upon which all moral and intellectual advances must be more or less based.

In the following condensed account of the great inventor and his wonderful work, the endeavour has been to secure the most authentic accounts of the history of the invention and of its introduction. In reference to its essential facts and dates, accuracy has been assured by drawing largely upon the published statements of Sir Henry Bessemer himself, and even, in some instances through inquiry of the inventor directly, and of his friends, and the men who have direct knowledge of the facts through personal observation. In collating these facts no trouble has been spared and it is hoped that the story, as here told, may be found to be equally accurate and interesting.

Certainly no event in the history of our time has so much of the marvellous connected with it, none illustrates more strikingly the singular and impressive aspects of metallurgy and of chemical

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and physical science, and none is more marvellous in its outcome, and in its effects, particularly, in the promotion of modern civilisation, and of the comfort and general welfare of the world. Parts of the story will be told in the words of the inventor himself, and it will be none the less graphic and interesting for that fact. Sir Henry Bessemer disclaims all talent in authorship; but few men can state an idea more clearly, or, in the description of any event, can use more luminous diction.

Sir Henry Bessemer was born at Charlton, Hertfordshire, England, on January 19, 1813. He was of semi-continental origin, and of a stock distinguished by character and genius. His father was Anthony Bessemer, whose beginnings in the study of mechanics were made in Holland at the age of nine years, and who, at twenty, constructed a floating steam engine to drain the turf-pits near Haarlem. Like so many ambitious young men of the time, he was attracted to Paris. Settling there, he made improvements in the microscope and became a member of the French Academy at the age of twenty-five.

He was extraordinarily successful as a type-founder, discovering the type metal alloy, composed of copper, tin, and bismuth, previously unknown, and not only made a form of type which was specially advantageous, but also employed this composition, giving them much greater endurance. His type wore twice as long as that of other type-founders of his time.

When the French revolution of 1792 broke out, he was employed in the mint, illustrating there his great talents as inventor and administrator. Upon the accession of Robespierre to the directorship, he was ordered to take charge of the public bakery, then established to supply the people of Paris with bread. A false rumour getting abroad that the loaves furnished by the bakery were of short weight, the populace rose against the establishment, and its manager was compelled to flee the country to escape the dangers threatening him. He went to England, and the destruction of the fortune of the young engineer and inventor proved, ultimately, a source of profit to himself and of untold wealth to the nation.

Anthony Bessemer, arrived in London, promptly secured a position in the mint, and there gained a modest fame and began a fortune by steady industry and by the application of his inventive talent to the solution of the many problems brought to him in the course of his work. He invented new methods of type-founding, still further improved his microscope, and was the first to successfully reduce gold from the solutions then usually wasted by the jewellers. This process was only superseded, thirty years later, by the invention, by the Elkingtons, of the electrolytic systems now employed.

He finally established a type-foundry at Charlton, under the firm style Bessemer & Catherwood; his partner supplying the required capital. The enterprise proved a success, and the inventor lived throughout the remainder of his life, and finally died, at Charlton, possessed of a moderate fortune and leaving his son a greater inheritance in the record of a well-spent life. More than all, however, the boy was fortunate in his possession, by heredity, of his father's talent for invention and for mechanics and engineering.

These gifts were displayed by the boy in his earliest years, and cultivated continually throughout his life. His toys were tools, and his youth was spent, very largely, in the development of his mechanical powers in the use of machine tools in construction, and especially in acquiring the art of turning with a beautiful Holtzaffel lathe, given him by his father. He also developed a talent for sculpture. Some of his modelling in clay is said to have been exceedingly artistic.

Young Bessemer spent his boyhood at Charlton until he was sent to school at Hitchin, where he gained the elements of an education. His leisure was given to his workshop and the development of his genius for invention and mechanics was stimulated by the then famous achievements of Jacob

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SIR HENRY BESSEMER IN 1866, AT THE AGE OF 53.

Perkins, an American inventor, settled in London, and by those of no less distinguished contemporary British engineers. As the youngest son, Bessemer began, at an early period, the management of his own affairs, and independently sought to make his own way in the world. At the age of eighteen we find him in London, where he took up the business of designing and modelling, and with immediate success.

One of his first successes in the metropolis came to him a year later when he exhibited one of his beautiful models at the Somerset House exposition of the Royal Academy, and another and more important one was gained when he invented a new stamp for the British Stamp Office. This was the perforated stamp now familiar as a cancelling stamp and for other purposes, and this was improved upon, as Sir Henry himself says, by the young lady to whom he was at the time engaged to be married. She suggested the use of the date as an integral part of the stamp, thus making

it impracticable for a previously possible fraud to be perpetrated by the transfer, or by the alteration, of the older stamp. As the loyal inventor says, "she so improved upon my invention that her plan was accepted, and an act of Parliament passed in six weeks, making her plan the only legal stamp in Great Britain; and so it remains to-day." It was largely in acknowledgment of the advantage conferred upon the nation by this simple yet important invention that Bessemer was, later, knighted, and "thus," as he goes on to say, "she shares the title and is Lady Bessemer." The stamp office accepted, first the one, then the other, of the two devices, and the latter is to-day the legal form of British stamp.

The officials of the stamp office had told Bessemer that the government was probably defrauded of £100,000 a year through the ease with which the older stamps were manipulated. This was saved, and probably more, by the new device. It was intimated to the inventor that a position in the office, at £600 or £800 a year, would be assigned him, in acknowledgment of his services; but it was never given him, and it was only in 1878 that knighthood was tendered him as an honourary compensation for his, by that time, immeasurable service to the country and the world. The invention was not patented, and the inventor could do nothing to enforce his equitable claim upon the government. He soon saw that it would be useless to waste time or money in the attempt. As he says:—

"I could not go to law, even if I wished to do so; for I was reminded that I had done all the work voluntarily and of my own accord. Wearied and disgusted, I at last ceased to waste time in calling at the stamp office—for time was precious to me in those days —and I felt that nothing but increased exertions could make up for the loss of some nine months of toil and expenditure.

Thus, sad and dispirited, and with a burning sense of injustice overpowering all other feelings, I went my way from the stamp office, too proud to ask as a favour that which was indubitably my right."

Bessemer was at this time twenty years of age, with a fortune still to be made, unable yet to look forward with confidence to a time when he could marry the young lady of his choice, and so situated that the disappointment was most serious. But he was not made of the stuff that permits easy or permanent depression and he soon engaged, with as much zeal as ever, in new plans. The success of his work, if not his personal gain, was encouraging, and he found himself promptly involved in a number of promising schemes. He invented a machine for the production of figured Utrecht velvet, and apartments in Windsor Castle soon illustrated the value and beauty of his work.

He next took up improvements upon the art learned from his father, at Charlton, and, on March 8, 1838, patented a machine which produced what are thought to have been, certainly up to its date, the most perfect type ever cast. He secured freedom from air and from "blowholes" by casting the type in a vacuum. The machine involved many of the principles of the later type-founding machines, and was a pioneer in that series of grand inventions. A few years later, the *Family Herald* was "composed" by a young woman, for some two years, employing a composing machine of Bessemer's construction, working at the rate of six or seven thousand types an hour, throughout the full working day.

Another of Bessemer's inventions, and one which resulted most fortunately for him, in a pecuniary sense, was the apparatus for the manufacture of bronze powder for use in painting and decorating. The raw material cost 11 d. a pound, and the powder was imported from Germany at a cost of £5 or £6, per pound. The young mechanic struggled a year and a half, gave up the attempt, resumed his labours after a six months' rest, and finally succeeded and at once set up the manufacture in England. He made a great success of this new industry, but he never patented his apparatus. It was

worked as a secret process for many years and finally was turned over to the faithful assistants who had preserved the secret so long, and who, in turn, operated the establishment many years. The profits were at first enormous, at least 1000 per cent., and, for a long period, several hundred per cent.

Bessemer was continually scheming out new devices and patenting new inventions. He studied the manufacture of paints, oils, varnishes and sugar, and endeavoured to improve railway and railway carriage construction, and making of heavy ordnance and projectiles. He invented improvements on the already known centrifugal pump, and almost daily struck out a new idea. He became known as "the ingenious Mr. Bessemer."

About 1880, the writer of this sketch proposed the construction of a railway train for exceptionally high speeds, which should have, among other peculiar features intended to decrease resistance and to increase safety, a continuous, smooth, yet flexible, exterior shell, with vestibuled connections and a conoidal terminal portion covering the engine, the whole making a cigar-shaped mass which, as was supposed, might be driven at the speed of a hundred, or, if found in other respects practicable, at a hundred and fifty miles an hour with minimum resistance and engine power.

On investigation of the records, he found that Sir Henry Bessemer had antedated him by above thirty years. That great inventor had, in 1847, patented improvements of a similar character, and had, in the course of his work of development of his invention, made a series of extraordinarily interesting experiments at what were then considered very high speeds, finally winding up his work by "ditching" his train. He proved that the resistance of even the pile of luggage on the top of the carriage—as then customarily carried, instead, as in the United States, in a separate "luggage van" or "baggage car"—was productive of great wastes of power and sensible loss of speed. A single portmanteau, at thirty miles an hour, would thus prove as much of a load as a ton weight inside the carriage. At sixty miles an hour, it would be equivalent to five tons, and at a hundred miles, to about nine tons. He showed that the spaces between the several carriages of the then loosely-coupled trains of English roads were also a source of loss of power. The result has been the removal of all luggage from the tops of carriages, the introduction, universally, of the "luggage van," and the closer coupling of carriages.

The most advanced practice in this direction is illustrated in the United States in the vestibuled trains and the invariable employment of the "baggage car," the latter practice dating from the earliest days of railway operation in the United States. But the Bessemer system of train construction, with its smooth exterior, its form of least resistance, and its conoidal ends, is one of those inventions which have been made too early and some future time will see it reduced to everyday practice, with, very likely, little honour accorded to its original inventor. At the high speeds now coming to be recognised as perfectly practicable,—provided travellers are ready to pay for them,—the Bessemer train construction will reduce the resistance and raise the limit of speed to such extent as to prove, there can be little doubt, a desirable as well as practicable device.

In 1851 Bessemer exhibited several inventions at the International Exposition and attracted much attention and great admiration on the part of the mechanics of the time. These exhibits were his centrifugal pump, his sugar separator, and his plate glass polishing machine. The pump was stated to be capable of raising twenty tons of water an hour, draining an acre of land, flooded a foot deep. The sugar separator could drain sugar from molasses with twice the speed of any previously invented apparatus. The glass polishing machine was peculiarly ingenious in its method of securing the plate to be polished, and releasing it when the work was done,—operations that had previously demanded much time and

compelled the use of tons of the plaster of Paris, employed as the cementing material.

The method adopted by Bessemer was to score the table or platen on which the plate glass was supported, then exhausting the air from these grooves in such manner as to firmly hold the plate down by the superincumbent atmospheric pressure. These inventions all proved valuable improvements. The centrifugal pump is doing its work all over the world; the sugar separator is now in general use for its special original purpose, and other uses, as the separation of cream from milk, are being found for it. The plate glass polishing apparatus was pronounced at the time, by authorities then well recognised, as among the great inventions of the day.

In 1854 war broke out between Russia and the, for the time, allies, Great Britain and France. The coming event had long been foreshadowed, and Bessemer was led to consider the subject of improved ordnance and projectiles. The army and navy guns were, at the time, smooth-bored and their projectiles spherical. Rifled cannon were not yet successfully introduced although the principle had long been known and Cavalli and Wehrendorf —the one in Sardinia and the other in Sweden,—had experimentally employed it in 1846, in heavy ordnance. Rifled cannon only came into use, permanently and as standard forms of construction, about 1860, the first used in war being, probably, those employed in the Italian campaign of 1859. Elongated shot and shells, for use in smooth-bored guns, had been proposed and experimentally—it is said successfully—used by Robert L. Stevens, in 1813; but the construction was kept secret and finally sold to the United States government, and by it neglected until absolutely lost. Some of these were percussion shells. In 1854 the world was apparently as ignorant of the idea as if it had never been proposed.

Bessemer invented shells of such form and saw promise in the plan, as devised by him, and enthusiastically strove to bring it into use. The required rotary motion, usually now conferred upon the projectile by "rifling," was, in his shot, produced by channels in the shot in which the reaction of the passing powder-gas and air gave the needed impulse and the necessary rotation. His gun was given an enlarged chamber for the purpose of condensing and giving better form to the charge, while an enlarged exterior and a built-up construction gave his ordnance still closer resemblance to the powerful guns of our own time, of which it was, in some degree, progenitor.

As the inventor put it,—"By this mode of making guns in various parts I am enabled to use iron and steel in some cases, and thus to form a gun of great strength, the parts of which are of little weight, while it also admits of the various parts being made of the metals most suitable to resist the peculiar strains and wear to which they are severally subjected when in use."

The results of his experiments were communicated to the British government; but they received no favour and a happy accident bringing Bessemer into the presence of the Emperor of the French, when on a visit to Paris, that monarch, more intelligent or more liberal than the compatriots of the inventor, gave him *carte blanche*, and every facility for the conduct of his experiments at Vincennes. There, experiment proved that Bessemer's claims were absolutely correct, and elongated shot were fired from smooth-bored guns with ample rotation to keep them "end on" and in true line of fire. It was found possible to secure two or three rotations in the length of the bore of the gun, and their passage through a series of screens showed their perfect retention of their axes in the line of their trajectory. The British war office took no interest in these experiments; but the French Emperor saw Bessemer fully compensated for all his time and expenses in the presentation of his invention to the French government.

Enough was accomplished to show Bessemer, and the artillery officers witnessing his progress, that it was im-

portant to find a stronger gun-metal, to insure permanent success in the proposed improvement of ordnance and gunnery. Bessemer returned to London with this idea in mind, and with the intention of seeking some better gun-iron or other metal, capable of serving his purpose. Naturally, his first thought was the adaptation of some form of steel to gunnery, or the production of some similar material which should be capable of being worked into large masses without serious loss of tenacity and ductility.

Bessemer's experiments took the form of refining cast iron, a metal which had ordinarily too little strength for satisfactory use in heavy guns, and which was almost absolutely brittle. By refining the common irons of the country, he succeeded in greatly improving them, and, after a time, returned to Paris to present to the emperor a gun made of this improved metal, which was much stronger than the then usual qualities of gun-iron. It was a white cast iron, very strong, but presumably of little ductility, although, as he tells us, it was both "tougher and stronger than the best cast iron then in use for artillery purposes." The gun was accepted with promptness, and due acknowledgments were made the inventor.

By this time Bessemer's eyes began to be opened. He says:—"I now saw that the refinement of iron in the fluid state might go on until pure malleable iron or steel would be obtained, and I fully realised the fact that such a result, in importance, went infinitely beyond the mere production of a metal suitable only for the construction of ordnance."

A year had passed in his experiments before he was ready to offer his first gun to the Emperor of the French. It was eighteen months more before he saw clearly that it would be possible to remove the carbon from cast iron by simply forcing a current of air into it, and that it might be rendered malleable in that manner. His first direct experiments in this line were made in the laboratory, blowing air, with a portable blowpipe, into molten cast iron in a crucible, and producing ten or twelve pounds of malleable iron. Taking the ingot to the Woolwich Arsenal, it was proved to be what has been later called "ingot iron," and Colonel Wilmot, the superintendent, and Professor Abel, the chemist of the works, were intensely interested.

Every facility was given Bessemer for the testing and working of his new metal and it soon became evident that "the principle of purifying pig-iron by atmospheric air" was a sound and practicable one. Bessemer's first patent was accordingly taken out in October, 1855, embodying his earliest plan—that of reducing the metal in a crucible with an air blast. The experiments were then continued, looking for a method of forcing the air into the mass of the molten metal; but so many difficulties and so much of trouble and anxiety were consequent upon this effort that the inventor broke down and took to his bed, nervously exhausted.

But even while lying in his bed, his mind continued to run upon his great problem, and he presently concluded to try the experiment of forcing air in large volumes upward through a correspondingly large mass of molten iron in a great egg-shaped vessel, fitted up with suitable passages, taking the air from the blowing engine, conducting it beneath the vessel, and introducing it at the bottom, whence it might find its way in bubbles and streams throughout the fluid mass.

On recovering from his illness, Bessemer proceeded at once to the development of his latest idea, and soon had a circular vessel ready, which was about 3 feet in diameter and 5 feet in height, designed to contain seven hundredweights of molten iron. To this was connected the air blast from a small blowing engine, built for the purpose. This "plant" was set up at Baxter House,—a place which he had, meantime, rented for the purpose,—and, lining the vessel with fire-clay and charging it with molten iron, the blast was applied in presence of the inventor and the few people on the place at the time.

Jeans, describing this experiment, says*:—"Instantly out came a volcanic eruption of such dazzling coruscations as had never been seen before. The dangling pot-lid dissolved in the gleaming volume of flame, and the chain by which it had hung grew red and then white as the various stages of the process were unfolded to the gaze of the wondering spectators." The process was a success; steel was produced, and its quality proved to be good. Bessemer was sure of his fame. He patented his new system of steel production on February 11, 1856, specifying both air and steam as available reducing agents, although he was not able to make the use of steam successful, and though earlier experimenters, in modified ways, had been similarly unsuccessful. Sir George Rennie was invited by the inventor to witness these experiments and to give his opinion relative to the advisability of making them known. He advised publishing the process at once,

* Creators of the Age of Steel, p. 37.

in a paper to be read before the British Association for the Advancement of Science, at its coming August meeting at Cheltenham.

Bessemer read his paper "On the Manufacture of Malleable Iron and Steel Without Fuel," on August 11, 1856. Thirty days later, he had received £27,000 for licenses to use his invention,—"a fact which," as he says, "is sufficient evidence of the sweeping nature of the change which, even at that early stage of the invention, it promised to effect in the great iron industry of the country." Nevertheless, full success was not yet achieved, and a period of struggle and trial of considerable duration was still to be passed through by the brave and persistent inventor before he could feel assured that it would become an established process of manufacture.

In his famous paper, read before the Mechanical Section of the British Association, in 1856, Bessemer thus describes his fundamental ideas and theory:—"I set out with the assumption that crude iron contains about 5 per cent. carbon, and that carbon cannot exist at a white heat in the presence of oxygen without uniting therewith and producing combustion; that such combustion would proceed with a rapidity dependent on the amount of surface of carbon exposed; and, lastly, that the temperature which the metal would acquire would be dependent upon the rapidity with which the oxygen and carbon were made to combine, and consequently that it was necessary to bring the oxygen and carbon together in such manner that a vast surface should be exposed to their mutual action in order to produce a temperature hitherto unattainable in our largest furnaces." Next he described his process, as actually conducted, and its resulting product, and showed both the correct theory and the actually effected production of a metal having all the properties of the finest iron, transformed out of the crudest forms of pig-iron, without the use of fuel and at a cost evidently marvellously slight.

NIGHT IN A BESSEMER CONVERTER HOUSE.

The reading of the paper produced an enormous sensation, and neither the scientific men of the time nor the most experienced and the wisest of the iron and steel makers knew precisely how to receive the wonderful tale. The "practical men" were very much inclined to incredulity and often unreservedly ridiculed the claims made for the new process. But Baxter House, St. Pancras, was visited by increasing numbers of interested visitors, and impromptu experiments were made at various British iron and steel works, notably at the Dowlais Works in Wales.*

The French Emperor, now always interested and favourably disposed in any matter in which Bessemer was engaged, proposed introducing the process at the Roulle Arsenal, and the authorities at Woolwich Arsenal indicated a similarly favourable inclination. In September, 1856, an exhibition of the working of the pneumatic steel-making process took place at Baxter House in the presence of about seventy-five eminent iron and steel makers and scientific men. The experiments were thoroughly successful, and the steel produced was sent, in part, to Woolwich, where it was rolled into thin sheet metal and, later, punched cold into forms demanding the utmost ductility and malleability of the best Swedish plate.

A witness of the exhibition at Baxter House stated, in print, shortly afterward, that, after a blow of twenty-four minutes, the blast was turned off, the metal run into an ingot-mould, and proved to be of admirable quality. "The whole experiment was conducted with a degree of precision and neatness that would have done honour to a Faraday, a Turner, or a Dalton." Five iron masters, in as many districts, into which the kingdom was divided by Bessemer, accepted the proposals of the inventor and took out licenses, the Dowlais Company leading, and the manufacture was fairly organised in Great Britain, with, apparently, no possibility of failure or serious obstacle.

But "there's many a slip 'twixt the cup and the lip," and what seemed an awkward slip took place immediately upon the attempts of the principal iron masters to avail themselves of this seductive process. Uncertainty and often positive failure and condemnation characterised the few months following this brilliant debut of the Bessemer process. The process was formally condemned as a failure by iron masters of Staffordshire and Worcestershire, at a meeting held by them but two months after the invention had been published at the convention of the British Association for Advancement of Science. The steel made by the process at Dowlais proved comparatively worthless, and failures were reported on all sides. Nearly every experiment failed, although the experimenters were confident that they followed precisely the method adopted by the inventor himself. Development of the Bessemer system came to a full stop. Discouragement was seemingly universal,—except with a single individual, Henry Bessemer, the indomitable inventor.

Absolutely convinced that his earlier experiments could not be gainsaid or overthrown, and that what had been done before could, under similar circumstances, be repeated as often as desired, he continued to study all difficulties as they arose. He had made good steel; his licensees had not. These facts simply pointed out the existence of conditions in their operations which were absent in his own, and he patiently and steadily went about the discovery of these unexpected obstacles to general success. He analysed pig-iron and product, compared brand with brand, and ingot with ingot, and sought in the chemistry of the process a reason for such strange differences in outcome as had been revealed when others attempted to effect a result by him always reached without difficulty. As a matter of course, scientific investigation, in time, solved the problem.

In the manufacture of steel by the then only satisfactory process,—the

* Six weeks after the date of this paper, the same experiments were made by Messrs. Cooper, Hewitt & Co., at their works in the United States.—Transactions American Institute Mining Engineers, 1882, Washington meeting.

melting of metal in a crucible, after previously introducing the carbon by the cementation process—similar difficulties had originally been encountered by its promoters. It was, after a time, found that only certain kinds of iron were fitted by composition and intrinsic quality for the purpose of steel-making. These irons became the acknowledged sole sources of crucible steel. It was further found that it was necessary to introduce into the melting pot, usually, some compound containing manganese, to insure perfect soundness and highest quality of product, especially in making steel for the finer uses.

It came to be known, later, that all molten metals take up, and perhaps dissolve, oxygen in considerable volume, precisely as does water reacting with carbonic acid, or as is illustrated most strikingly in the case of silver, which takes up so much of the gaseous oxygen, when itself fluid, that its expulsion on the solidification of the metal produces, often, a real explosion, and gives the masses of silver, thus affected, all sorts of curious, and frequently beautiful, rose-shaped forms. The presence of oxygen in molten steel doubly injures it, directly reducing its tenacity and its ductility, and exposing its molecules to oxidation, and, thus, indirectly further destroying its toughness and its value for all purposes. The introduction of the more oxidisable metal, manganese, fluxes out the oxygen, and, further, improves the steel by, in some way, ameliorating the deleterious effects of other elements present in almost all iron ores and in nearly all irons.

The one element which is most troublesome in all processes of production of iron, and even more in steel making, was not removed or appreciably reduced in the pneumatic process of Bessemer. Phosphorous produces "cold-shortness" in a remarkable degree, and the most minute portions of this element sensibly injure the quality of metal intended for the finer uses. In tool-steel making, even the most insignificant measure of this substance is avoided in choosing iron proposed to be carbonised and every precaution is taken to secure an iron which has been obtained by reduction of ores quite free from phosphorus.

The reason of the non-success of the attempts of his licensees to utilise the Bessemer process were discovered, after a time, to be due to the fact that, in every case, they had employed irons in which the proportion of phosphorus was high. It had happened, by singular good fortune, that Bessemer's first experiments had been made with Blaenavon pig, and, this iron containing no appreciable proportion of the deleterious ingredients, they were, for this reason, satisfactory. The great majority of the British ores are phosphoritic and unsuitable for use in the process of Bessemer as then practiced. The difficulty was early pointed out by chemical analysis and was recognised by Bessemer himself. It became at once generally believed that the pneumatic process was of little or no value, since it could not eliminate this noxious element.

A long and patient search for an antidote for the poison followed, occupying months of arduous and systematic scientific work. Constant experiment, continuous analyses of ores, of irons and of the products of the new process, convinced the inventor that it was simply excess of phosphorus that stood between him and success and wealth and fame. But nearly every independent experiment resulted in exhibiting the same facts, and it became evident that the common ores and irons of the country were unfitted for use in that manner.

The receipt, after a time, of a quantity of Swedish irons, which had been ordered in view of their general use in the tool-steel manufacture, permitted the trial of such irons and the immediate settlement of every difficulty. They gave such admirably pure and excellent Bessemer steel, that all attempts to find a way of using native irons were at once and definitely abandoned by Bessemer and, thereafter, only what came to be known as the "Bessemer ores" and the "Bessemer irons" were employed. Once this became the established

method, all serious difficulties were at an end and ores and irons from Sweden and Norway, from Spain and from North Africa, and, in Great Britain, from the Barrow and Whitehaven districts, supplied all makers with "Bessemer steel."

Steel was not yet produced, however, by this process. It was found practicable, starting with fine irons, to make a pure malleable iron from the pig by a treatment, such as has been described, in the Bessemer "converter;" but to make steel, required that the "blow" should be stopped at precisely the right instant, to leave in the metal just the exact proportion of carbon needed to give the quality of steel desired.

When it is remembered that all the steel in our markets, ranging in quality from the softest "ingot-iron," employed in drop-forgings and in boiler-plate, to the machinery and tool-steels, are contained within the range, carbon one-eighth, to carbon one, or one and a quarter per cent, it will be seen that this must be a most delicate operation. It so proved, and it was concluded that a commercial success could not be confidently expected if it were to prove necessary to obtain, at each blow, precisely the specified quality of product for a stated purpose. Bessemer produced from his Swedish pig-iron a metal which contained but 0.16 per cent.,—fourteen parts in a million,—of foreign matter. It was one of the purest and finest samples of malleable, or wrought, iron that ever was seen; but he could not, at that time, produce an ounce of steel of a definitely specified quality at a single "blow."

The soft irons actually made were comparatively useless and valueless in the arts. What was wanted was an iron hard enough and strong enough for use in structures in which combined strength, ductility, elasticity, and wearing power were desiderata. These were not the distinguishing qualities of the product of the pneumatic process as known to the metallurgical world of Bessemer's days of "Sturm und Drang." The process proved too perfect in its reduction of the highly carbonised pig-iron to the malleable form. Pure iron is worthless iron for all the engineer's purposes and can find no market. Steel was wanted, and steel of various grades and percentages of carbon, produced to order, and of precisely the quality defined by specifications, stating the needed tenacity, ductility, and resilience.

Since experience proved that the stopping of the blow at just the required point to leave in the metal the needed proportion of hardening elements was impracticable, it at once followed that the pig metal must be converted into malleable iron, and that the latter must then be, in some manner, given the desired composition and quality. This meant, evidently, recarbonising; and this was the conclusion to which Bessemer was soon brought, after the facts which have now been related had been fully revealed. Experiment at once confirmed the deduction, and the pneumatic process was, at last, a success, and the triumphant victory of the indomitable genius promoting it now gave to the world the grandest and most fruitful advance in metallurgy that this century of wonders in that, as in all other fields, has witnessed, if not the greatest in the world's history. It stands beside the invention of Dudley and that of Cort.

It was now obvious that two elements must be employed in the treatment of the fluid metal after complete removal of the carbon in the converter. Manganese must be added to absorb dissolved oxygen and give general improvement of the metal; carbon must be added to the pure iron in the converter to give it the desired "temper," as the steel maker calls it.* The addition to the molten mass of a selected iron, containing both manganese and carbon in the right proportions, constituted the last step in the process of de-

* The "temper" of the steel-maker and the "tempering" of the tool-maker are entirely different things. The one designates the quality of the metal as produced by its higher or lower percentage of the hardening elements of its composition; the other indicates the production of a certain degree of hardness in a tool-steel by heating, suddenly cooling, and then adjusting the hardness to exactly that demanded by heating to a lower temperature than before, and finally quenching at the right stage.

velopment of pneumatic steel making, as finally perfected by Bessemer. Thus, after four years of additional labour, of enormous expense, of repeated discouragement, the process was perfected and patents were issued to its inventor for all its details. Ferromanganese was manufactured for use in the converter and recarburising was made the final step in the production of steel. In Sweden, in some cases, the pure cast irons of that country were employed for recarburising, but were thoroughly successful only when containing some manganese. The use of manganese is, practically, universal in the final treatment of the metal before pouring from the converter into the mould.

The process was perfected, but, meantime, four years of silence and disuse had thrown it out of the market, and almost entirely out of sight. It was necessary to start anew in its introduction, and to add to the £10,000, which had been lost in experiment, another large sum, to be expended in proving its value and in bringing it into use.

This task was entered upon with all the courage, the systematic method, and the determination which had characterised every step in the earlier work of the inventor. He sent to every iron producing section of Great Britain, and sent abroad as well, for samples of irons and ores, and sought out those free from phosphorus. He found the Cumberland hematite the most promising of all domestic ores and soon proved its fitness for use in his process. Steel was made of as nearly as possible the composition of the tool-steels then called for in the market, and was distributed among workmen and firms employing such metal, and thus, without the knowledge of the workmen handling it, tested. It bore the test and the inventor was satisfied.

On May 24, 1859, Bessemer read a paper before the British Institution of Civil Engineers, reintroducing the pneumatic process to the world. He explained the cause of his long absence from view, the difficulties which had arisen and had been successively and successfully overcome, the processes by which he had, one after another, vanquished them, and the final outcome of his years of undiscouraged struggling for a result which he had, all along, been confident must ultimately be attained. He described the method of reduction and of recarburisation, as finally perfected and then practiced, and concluded by exhibiting the product of the pneumatic process in the form of structural steel, showing its wonderful combination of strength and ductility, and explaining that this remarkable and, in fact, new material of construction could be made for a lower price than even ordinary puddled iron. This paper was given by the Institution the Telford Medal, its greatest award.

Among the illustrations of the successful production of various forms and as various qualities of steel, exhibited at this now historically famous meeting, Mr. Bessemer showed a small piece of ordnance, cast directly from the converter; a large steel circular-saw plate, worked out of an ingot made by his process in Sweden; bar-steel, made in France; and other examples of important uses, collected by him from makers who had, by this time, set the process in operation throughout Europe. The paper and these solid facts were sufficient to convince the most cynical and incredulous, and the inventor has ever since had little occasion to complain of delay or cessation of progress in the extension of its applications throughout the civilised world.

Yet, conservatism at first impeded the new development, until Bessemer had turned his attention to the conquering of those difficulties, which, at one time, seemed likely to prove more troublesome than the material obstacles that inventiveness and persistence had now vanquished. He determined to take the whole business into his own hands and make a business of the introduction of the process and its product. He bought back all his previously issued licenses, at a great advance over their original price, and set up works at Sheffield, in the very midst of his most active and powerful rivals and

competitors, for the specific purpose of showing the capacity of the method for the production of all qualities of steel.

He soon began sending out tool-steels to compete with the crucible steels of the time, and with immediate success. This make was sold for two years, and until the market was fully prepared to accept a Bessemer steel of that grade. Soft steel, or, more correctly speaking, "ingot iron," was made and found suitable for uses to which only the ductility and malleability of copper had previously been applicable. Every grade of hardness or softness, of high or low temper, of stiffness, strength, or cutting quality, was shown to be obtainable by this marvellously adaptable method. This latest victory was promptly won.

In a paper, read at a meeting of the British Institution of Mechanical Engineers in 1861, the now triumphant inventor wrote:—"Enough has already been said to show how important is the application of cast steel to constructive purposes and how this valuable material may be both cast and forged with such facility and at a cost so moderate as to produce, by its superior durability and extreme lightness, an economy in its use as compared with iron. The construction of cast steel girders and bridges, of marine engine-shafts, cranks, screw-propellors, anchors and railway wheels, are all deserving of careful attention. The manufacturer of cast steel has only to produce at moderate cost the various qualities of steel required for constructive purposes to insure its rapid introduction; for, as certainly as the age of iron superseded that of bronze, so will the age of steel succeed that of iron." This prediction was long since fulfilled, and to-day sees almost every article of construction formerly made in iron now produced, of better quality and at a lower cost, in steel.

The International Exhibition of 1862, at London, gave Bessemer an opportunity to display to the world the evidences of the singular, the varied, and the enormously valuable uses to which, by that time, this new and wonderful metal had been applied. Of this opportunity he fully availed himself. As he says in his letter of 1878 to the British Secretary of State for the Home Department, describing some of his struggles against so many obstacles, he "exhibited two steel cannons, one in the rough state, the other bored and finished; also steel projectiles of various sizes; portions of a very large gun; Enfield rifle barrels, of which thousands had been made; bayonets, swords, pistols, etc.; also wire for cables; ship's plates, rails, wheel-tires, bars, rods, files, cutlery and cutting tools of every description. These were all arranged in the large area so liberally allotted to me, before the eyes of all the world, and safe from any private or summary condemnation. Here, at least, I felt that my invention would stand or fall, purely on its own merits, and I was fully prepared to accept the verdict."

In a recent letter to the writer, Sir Henry Bessemer, referring to the same subject, says:—"It struck me that in the country where so many millions of steel nails are now used, you might feel interested in seeing a few of the first that were made. They formed part of my exhibit of 1862 at the great show in London where I had specimens of almost every article that can be made in steel. For this purpose, the directors gave me a space, 35 feet square, with an 8-foot gangway all around it. I called personally on many large manufacturers and asked them to make articles in their trade with my new steel. Thus I got swords, bayonets, shields, rifles, pistols, ordnance, projectiles, boiler-plates and tubes, piston-rods, locomotive tires, crank-axles, connecting rods, wire of all sizes, from one-half inch to the size of a hair, wire ropes, hydraulic cylinders, large screws, tools of all kinds, cutlery, etc.; in fact, an enormous catalogue of exhibits and of the finest workmanship. My only claim was that it was all Bessemer steel." Everything was marked with the name of the maker, and, as Sir Henry says, he exhibited for them as well as for himself.

The International Exhibition of 1862,

in London, was thus the opening of a new era in the history of the struggles and the busy life of Bessemer. As he states in the letter just referred to, "a few days after the opening of the exhibition, in May, 1862, Mr. John Platt, M. P. for Oldham, came to me and said that he and a number of his friends desired to become interested in my patent and asked me to name a price for which I would sell a quarter share to him and nine others. * * * I told him that I would not have partners who would overrule me. I was getting £2 a ton on all ingots made, allowing a drawback of £1 a ton on all ingots made into rails. This was a high royalty, and possibly I might see wisdom in lowering it at a future time and my partners might not agree to this. I therefore declined to sell a share of my patents.

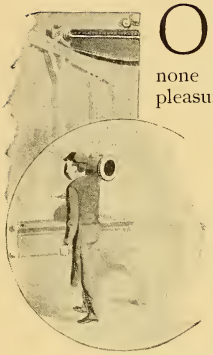
"A few days later, Mr. Platt again came to me and said that they were willing to give me absolute power and discretion to deal with the patents and royalties as I desired. They were willing to have no control whatever over my patents so long as I was the owner of not less than half. This removed my objections and I entered into a bond with them to hand over to them five shillings in every pound that came into my possession as royalty, one-fourth part of the receipts; but this did not involve either partnership or contract. I named £50,000 as the price and this was accepted, and within three weeks of the opening of the exhibition I dined with these ten gentlemen at the Queen's Hotel, at Manchester, and each of them, after dinner, handed me a roll of £5000 in bank notes, and I had the pleasure, a few years later, of handing over to them, half-yearly, a gross sum equal to £260,000."

The most perfectly friendly relations continued among these partners to the end, and, after the expiration of the patents and the consequent termination of the arrangement, Mr. Platt and a deputation of his colleagues presented Lady Bessemer with a large portrait of her husband as a testimonial of their appreciation of his talent, fairness and courage throughout that long period.

(*To be Concluded.*)

THE MILLING MACHINE FOR GENERAL SHOP USE IN AMERICA.

By Henry B. Binsse.



OF all the varieties of machine shop practice, I can think of none so full of interest and pleasure to the visitor as the manufacture of rifles and small arms. The order and system reigning everywhere, even in the littlest details, excite admiration, and it is delightful to watch the ease with which the work proceeds from the rough to the finished state. The different parts of the lock and breech mechanism appear at first in the form of steel drop forgings, blocks of dark metal, revealing little or nothing of the finished shape which they will assume.

These pieces are finished from the rough state by milling machines chiefly, each machine taking one cut only and, therefore, it is necessary to follow the working of several machines before the final shape of the detail begins to show itself. The operations are performed so easily, so rapidly and with such obvious accuracy that the lathe, planer and kindred tools seem crude and but half worked out, when compared with the perfect, semi-automatic action of the milling machine.

In addition, the armory milling machine attendant has his life lines cast in far easier places than his fellow mechanic of the machine shop. He has time in plenty to spare. Usually, he takes charge of a group of millers; he strolls from one machine to the other, takes out the piece which has just been finished, replaces it by another one, to which he gives a few playful taps with his hammer, tightens some bolts and starts up the machine again. Apparently, there is no trouble of any sort, no bother, and all the pieces are perfect, exactly alike, bright and shining with a beautiful finish,—a delight to the eye.

All this is in such sharp contrast with the manner that work is done in the machine shop, where the machinist is always busy, ever attentive to his machine, that we are constantly hearing of the milling machine being put forward for general shop use by those who know just enough about the ordinary run of machine shop practice to perceive the striking advantages of milling, but who have slight practical knowledge of its restrictions and difficulties. The truth is that the perfection of armory and sewing-machine shop milling is the reward of years of deep thinking and hard labour; and while there is, indeed, in the machine shop in general a wide and important field for milling, growing in value every year, these results can be gained only by a careful study of the problem. As an example of the superficial and sometimes absurd statements made about the milling machine, we may cite the words of a member of the prominent engineering societies who said, at a recent meeting, that the only difference between the milling machine and the planer was that in one case the tool went forward while in the other it went around.

In view of this and of similar erroneous impressions, it would be well, before proceeding to a discussion of our subject, to look with some care into the working of the milling machine. When we understand wherein it differs from the planer, we shall be able to see at

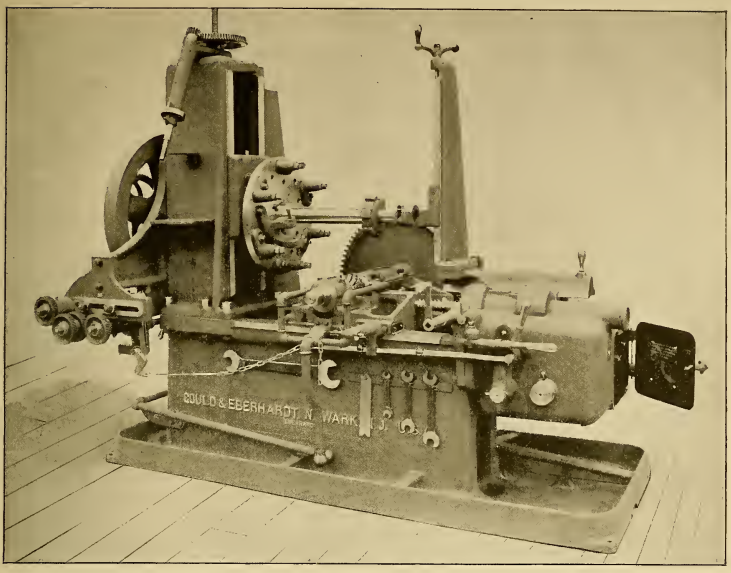


FIG. 1. GEAR CUTTER. BUILT BY MESSRS. GOULD & EBERHARDT, NEWARK, N. J.

once why its growth has been only along certain lines.

The difference between the milling machine and those machines which cut with a single tool is fundamental, in consequence of the two distinct methods of removing the metal. In the case of tools like the lathe, planer and shaper, all the work is done by a single cutting edge. Experience has led to the conclusion that here the cutting tool loses its edge and gives out more from pressure and friction than from the work of cutting. It would appear that the cutting edge is softened and dulled by the heat resulting from pressure, for we find that when we lessen the friction and pressure by lubricants, and by grinding the cutting edge to a shape which reduces the pressure, the life of the edge is increased.

Suppose that we had to cut the teeth of a spur gear with a planer. The general shape of the teeth having been roughed out, we would put in a finishing tool filed to the precise tooth contour. It would soon be discovered that as the cutting edge grew dull the teeth ceased to be alike. Naturally, then, the thought suggests itself to use a number of cutting tools, all alike in outline and to give to each tool so light a duty that it cannot wear appreciably; and this leads us at once to a revolving cylindrical cutter which can be turned in a lathe, composed of a number of

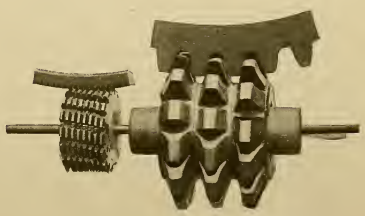


FIG. 2. A GANG OF CUTTERS FOR THE GOULD & EBERHARDT MACHINE.

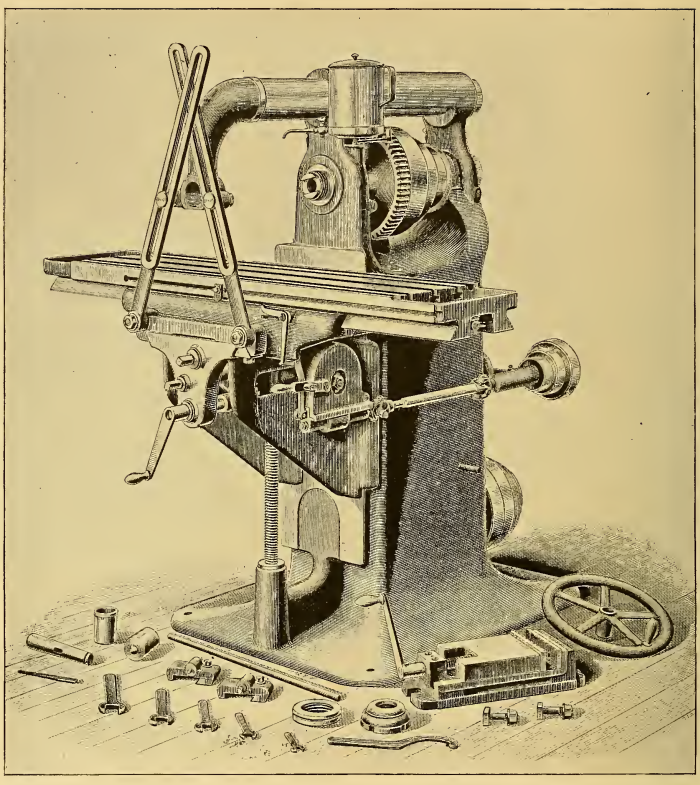


FIG. 3. A PLAIN MILLING MACHINE. BUILT BY THE BROWN & SHARPE MFG. CO., PROVIDENCE, R. I.

cutting faces, which are presented to the work in rotation.

The planer does its work by a stationary single tool, while the miller works with a revolving series of tools, and these conditions present engineering problems which vary greatly. In cutting with a single tool, the forces and resistances are practically constant during the entire cut, so that if either the cutting tool or the machine should yield a little from the cutting pressure, the workman can allow for it, regulating the feed of the cut accordingly.

It is an everyday experience that a skillful hand will do accurate and true work with a weak, poorly made planer or lathe. I have seen many remarkable instances of this. In one large machine shop in the United States, which had an excellent reputation for good work and which was an infirmary for ancient and decayed lathes and planers, they would point with pride to a long lathe, still in use a few years ago, upon which had been constructed one of the first machine-cut screws made in America. In another shop, when work was brought which was too large for the largest planer, they were used to taking

off one of the planer housings and, by reversing it and fastening it to the conveniently low ceiling, they transformed the tool into an open-side planer.

In sharp contrast with such simple, but bold, practice, the milling machine is most sensitive to the faintest tremble in the work, the machine or the cutter, and slight vibrations make chatter marks which spoil the work. The depth of cut which the cutting edge or tooth of the milling cutter will stand is much less than might be looked for; it varies, according to the circumstances, from less than a tissue paper thickness to that of three or four newspapers (0.001″ to 0.015″). Anything in excess of this destroys the cutter rapidly. It will be clear that with such thin shavings very faint vibrations show at once by uneven cuts. In addition, while the forces and resistances are constant with the single tool, they change every instant with the rotary cutter. Therefore, not only, on the one hand, does the milling cutter action tend to bring about vibration, but the result of such vibration is bad work.

It follows from these working conditions that the design and fitting of the milling machine must allow the least possible vibration or deflection either in the work table or in the cutter spindle, and that, if the product is to be smooth

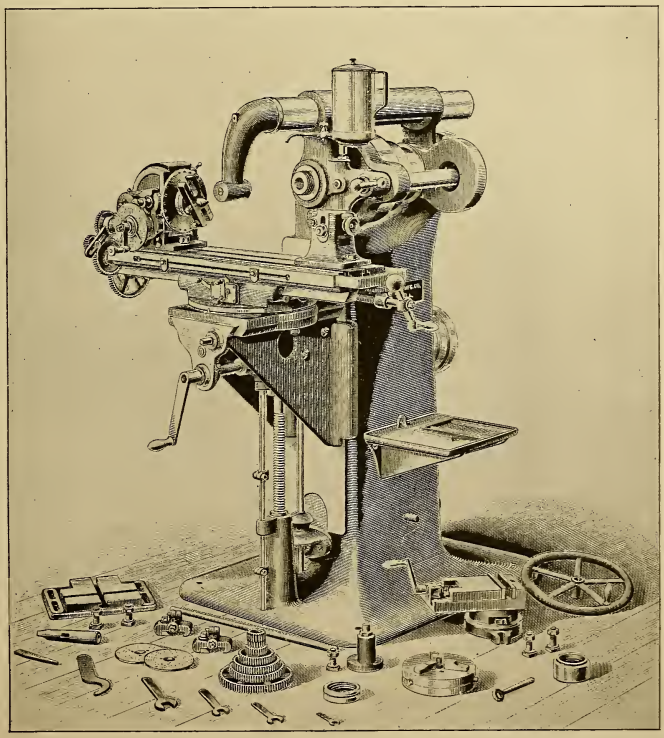


FIG. 4. UNIVERSAL MILLING MACHINE. BUILT BY THE BROWN & SHARPE MFG. CO.

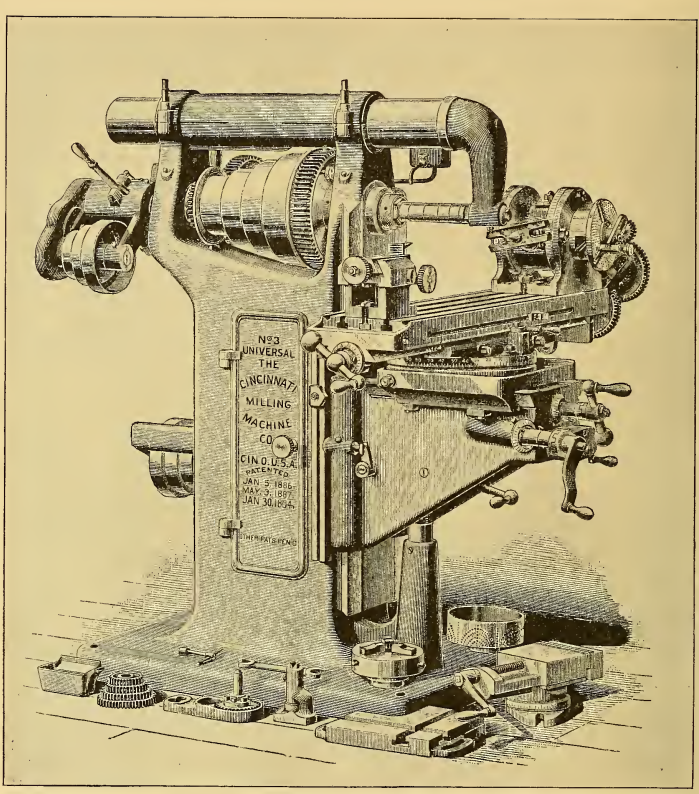


FIG 5. UNIVERSAL MILLING MACHINE. BUILT BY THE CINCINNATI MILLING MACHINE CO., CINCINNATI, O.

and accurate, the construction of the machine must be also of the most accurate and substantial kind. In fact, there is no other machine tool which exacts the same minutely careful design, or high grade of workmanship. There is little or no fine fitting and scraping in very many of the cheap lathes, planers and shapers which, for common work, give perfect satisfaction. The very beautiful, almost mathematically accurate, product which we admired so greatly at the armory, is the fruit of the untiring labour of the highly skilled tool makers who designed and built the milling machines and their fixtures, and who must continue to watch over them to see that they are kept in perfect order.

Not only is the first cost of the milling machine higher than that of other tools of like capacity, but, also, the cost of the cutters must be considered. Although the marked advance in cutter making has lessened their price in recent years, cutters of unusual size or shape remain very expensive. Gangs of cutters for form milling can cost from $25 to $100,—even more.

Bearing in mind the rigidity required

in the cutter spindle, we shall understand why milling cutters cannot be changed as rapidly as are the cutting tools of a lathe or planer. Moreover, the cutter must run as nearly true as possible (it never runs exactly true, except by accident), and every precaution must be taken to prevent chatters. Therefore, as the cutters should run as long as they may be without change, and on no account should be spoiled, it is important, for economical milling practice, that the material to be operated upon should be soft and, above all, free from sand, hard spots or scale. When it cannot be soft, as in cast steel milling, it must be homogeneous and thoroughly annealed. In this regard, the milling machine is at a great disadvantage compared with the planer.

Mr. H. L. Arnold mentions an interesting case of this, in a recently published paper on milling in *The American Machinist.* A very excellent example of milling machine had been built by the Pratt & Whitney Company, to mill some tee-shaped wrought iron elevator car guides. These were to be milled by a set of " straddle " cutters. The iron had been rolled before the machine was finished. At the makers' trial of the machine, it was found that the iron contained hard spots of rolling mill slag and scale, which ruined the cutters at once, making the machine useless for a time. This drawback is an important one, because the danger of hard castings is ever present in general work.

There are other difficulties in milling to which only brief reference can be made and which may be summed up roughly by saying that it costs more, usually, to prepare to do a job on the milling machine than it does on the planer. A review of these conditions will lead to the conclusion that the best field to-day for the milling machine is in the manufacture of large quantities of little pieces, like small arms and sewing machines, and it may be said that it is without a serious rival for this class of work.

While this is so, I should regret very much if I conveyed the impression that the usefulness of the tool is limited to this narrow range. Quite the contrary. As the machine shop of a past generation, where everything was undertaken, from a machine tool to mill gearing, has

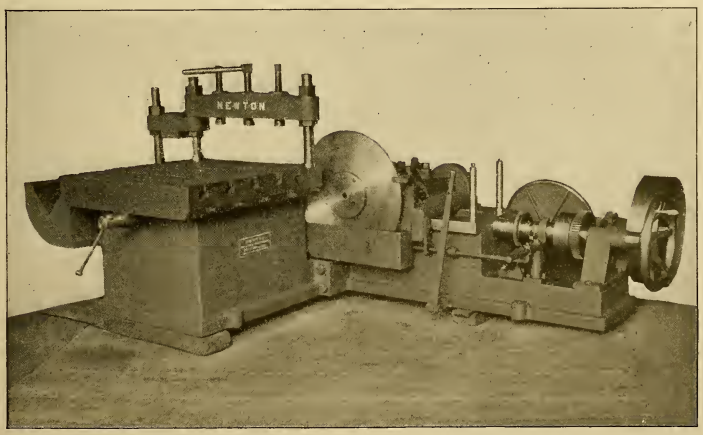


FIG. 6. COLD SAW CUTTING-OFF MACHINE. BUILT BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA, PA.

passed away and has given place to carefully designed factories for building machinery of a certain class only, striving to reach perfection in a very narrow line, so it may be said that machinery is being manufactured more and built less from year to year.

The milling machine, therefore, which is essentially a machine tool for duplication, and which displays its wonderful capacity only when there is a great amount of work of the same kind to be done, is coming more and more into use and is being more carefully studied and applied to a wider range of practice. Large milling machines in great variety have been brought forward during the past few years with most remarkable results; but it is necessary to repeat that the best returns are obtained by designing the tool for one kind of work, with as little range of size as practicable. We have an instance of this in the Eberhardt "New Type" gear cutter, shown in Fig. 1 on page 339.

The output of this machine will scarcely be believed by those who have not seen it. To the Messrs. Eberhardt belongs the credit of originating the first commercial full automatic gear cutter. Automatic gear cutters had, indeed, been constructed by Sellers, Bement, and others, but their cost was prohibitive. The automatic machine, brought out about twelve years since, was a marked advance over the ordinary gear cutter, because it completed the entire operation of cutting the gear, needing no attention after it had been started.

With the growth of the electric street car trolley system, came the demand for a machine which would cut the motor gears in large quantities. The process was slow with any machine of that day, because the pitch is coarse and the material, steel casting, is one of the most trying known to engineers. The "New Type" gear cutter was designed, then, to meet that want, which it does in a

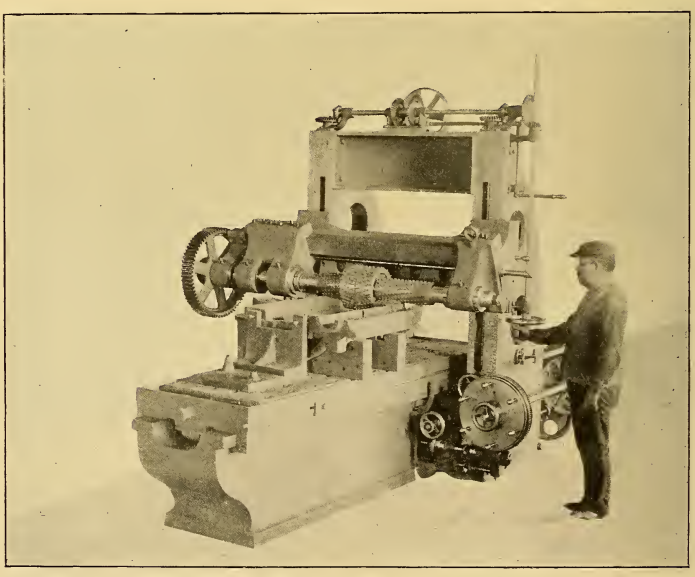


FIG. 7 SLAB MILLING MACHINE. BUILT BY THE INGERSOLL MILLING MACHINE CO., ROCKFORD, ILL.

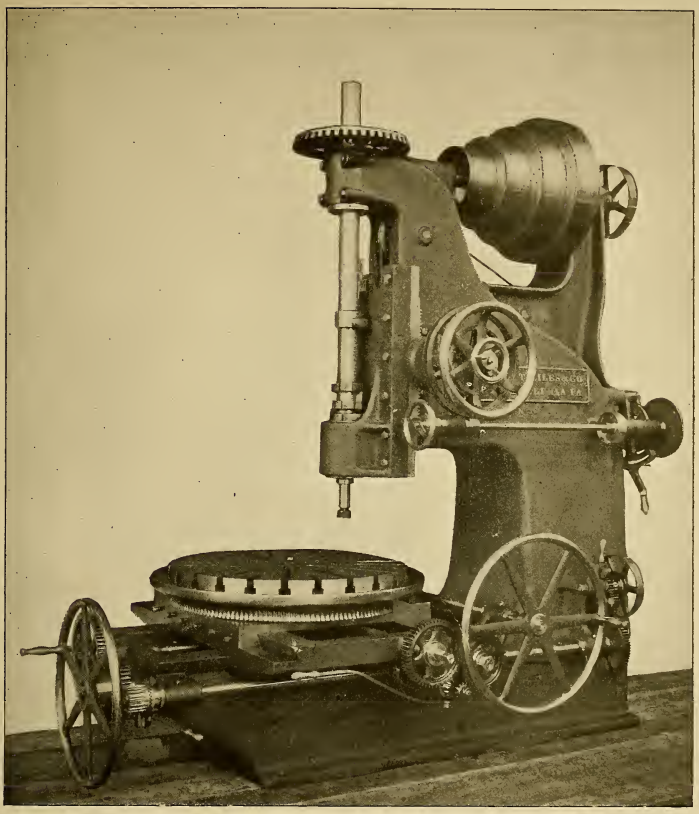


FIG. 8. HEAVY VERTICAL MACHINE. BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA.

marvellous way. Cutting three teeth at a time, it will finish a gear, 23 inches in diameter by 4½-inch face, steel casting, No. 3 pitch (about 1 inch circular), in from 2 to 2½ hours. The length of the cut is 5⅝ inches, the depth of cut being about ¾-inch, 1½-inch feed to the minute. The cutters are about 5¼ inches in diameter, and the cutting speed is 33 feet per minute. Those who have had experience with steel castings will appreciate what this product means.

It will be interesting to make a short analysis of the means taken to reach this result, which is about four times greater than the output of the usual machine. Examining the illustration, we will notice that the massive frame, heavy spindle, and generous wearing surfaces will resist any tendency to deflection and chatter. The spindle is braced by a very stiff end bearing and the gear is firmly held by strong dogs. In addition, six thick streams of lubricant are provided, three playing on the cutters in front and three in the rear,—a perfect deluge. This is a very important

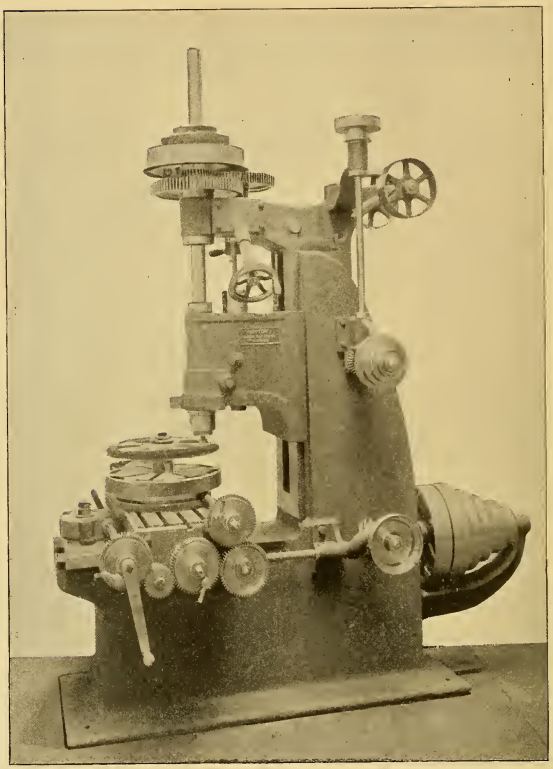


FIG. 9. VERTICAL UNIVERSAL MILLING MACHINE. BUILT BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA, PA.

point. Of course there is power to spare. Messrs. Gould & Eberhardt use a gang of cutters like that represented in Fig. 2. This shows three finishing cutters, but the cutters stand better if the gang consists of two finishing and two blocking cutters. Of course, the machine is not limited to motor gears. The cutter gang will cut only one size of gear.

There is a class of work for which a single cutting tool is so poorly adapted that time is always saved by giving the job to the milling machine. I refer to slot or groove cutting. This will include all kinds of key-ways, cutting off stock, rack cutting, and all similar work. All such work is best done on a milling machine, whether there is duplication or not. Of course, where special milling machines are warranted by the amount of work, the economy is vastly increased by their use. A special key-way miller will finish a key-way in about one-tenth the time that a planer or shaper would consume.

All machine shops, even those of moderate size, will find a plain milling machine, like the Brown & Sharpe, No. 4, shown in Fig. 3, almost indispensable for such work, as well as for much plain face milling and for work done by

"straddle" mills, such as nut finishing. This type of plain milling machine has been most carefully designed to enable the operator to change the cutter and to set the work rapidly. The cutter arbor is stiffened by the detachable yoke. A comparatively little sum for cutters will cover a great variety of work with this machine.

Another indispensable tool is the "universal," of which the Brown & Sharpe No. 2, Fig. 4, is one of the most perfect, and I might almost say, beautiful, examples. It is the only machine for making taps, reamers, milling cutters and small tools in general. The universal milling machine built by the Universal Milling Machine Company, Cincinnati, O., Fig. 5, has earned a high reputation in the last few years for the originality and merit displayed in its details, of which the feed handles arrangement and the variable feed are striking examples.

There are many designs of machines in common use for cutting off stock which is too large to be cut in the plain milling machine. No modern shop can afford to have this work done either in the lathe or by hand in the forge. Besides the rounds and flats in common use, wrought iron beams are being adopted wherever circumstances permit in places where, ten years ago, cast iron or wooden girders would have been the accepted practice.

Crane manufacture to-day affords one of the most striking examples of this change. The Newton Machine Tool Works, of Philadelphia, built a series of model machines for cutting off, covering every possible requirement and making a very interesting exhibit. A few years ago, this class of tool was unknown in the United States, except by scattered specimens of English machines. When the demand came for them they were promptly built, each problem being thoroughly solved, and in a way, to my mind, far in advance of European practice. The Newton No. 4 cold saw cutting-off machine, Fig. 6, will serve to illustrate the line. Of this tool, the makers write:—

"These machines are built in all sizes, from the small machine, cutting up to a limit of 2 inches, to the largest size, which has a capacity for cutting round sections up to 21 inches. These machines are now in universal use through-

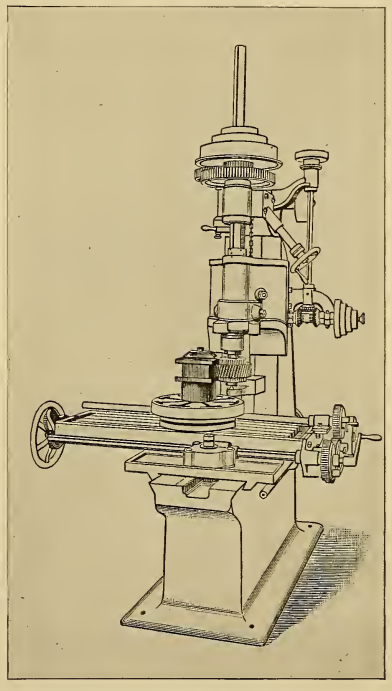


FIG. 10. FINISHING ROD BRASSES.

out the different machine shops, and the large forging shops are finding greater economy in using these machines on straight work than in using slotting machines. This No. 4 machine has a capacity for cutting square sections up to 12 inches, or is capable of cutting a slab 12 inches high by 38

inches long. The saw on the machine is 36 inches in diameter. The feed mechanism is arranged to have a feed one-eighth of an inch per minute on the slowest, up to one inch on the fastest feed. This is controlled by a lever which can instantly change the feed from one extreme to the other. The periphery of the saw runs at all times

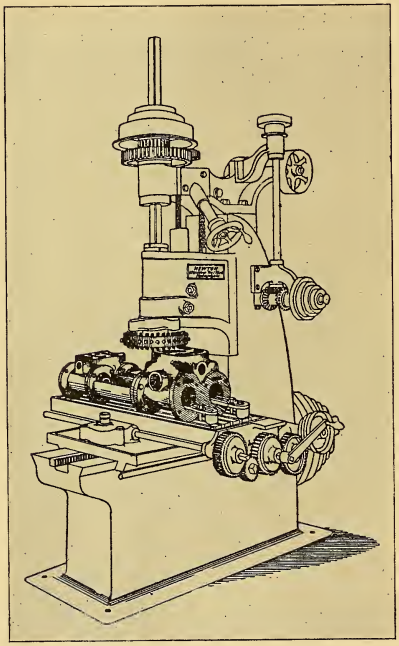


FIG. II. FACING THE VALVE SEAT OF A PUMP.

at the same speed. For ordinary work the saw travels 85 feet per minute. Where the machines are sold for cutting hard or irregular stock, such as high-carbon rails, we reduce the speed to 65 feet."

Another type of milling machine of great service in architectural iron work and similar construction is the face milling machine, sometimes misnamed the rotary planer. There are many varieties of this tool. Some have a single head only; in others, again, the head is fixed, the work being moved past the cutter. The work is fastened to tables and the heads move. A machine of this kind will be found very efficient for facing column ends, for the flanges of large cast iron pipe and connections, tees, ells and so on, as well as for valve flanges. The cutter is generally made by inserting regular octagon or square cast steel in a large cast iron flange, the milling being end or "butt" milling. It would be expected from what has been said, that milling machines would be used in the machine shops which manufacture but one kind of machinery in large quantities, like locomotive and railroad shops, steam engine works, pump manufactories and electrical works, and such is the case.

About the best machine for general service in machine shops is the vertical universal milling machine. Fig. 9 shows the Newton machine, one of the latest designs and with many excellent features, but there are many other varieties. Bement, Miles & Co., for example, have built some of them of extraordinary weight and power. This tool covers an unusually wide range of work, both heavy and light, of which Figs. 9 to 12 will give an idea. In Fig. 9 a hand wheel is being finished between the arms; Fig. 10 shows it at work on rod brasses; the valve surfaces of a pump are being faced in Fig. 11, and in Fig. 12 it is milling a key-way.

For milling large flat surfaces, both horizontal and vertical, there is an almost endless variety of milling machines, many of which have been designed with especial view to some particular job, but it is inadvisable for the purpose of this article to do more than to call attention to those which represent advanced practice and which are characteristic of the others. The Newton plain milling machine, Fig. 14, is used for milling locomotive guides and con-

necting rods, key-seating heavy axles, panelling locomotive rods, facing the halves of steel motor gears and similar purposes. This type of milling machine is built in eight sizes, covering a range as large as 72 inches square, by any desired length. The table is fed by a Sellers rack and spiral pinion, which gives a steady drive, the feed being varied by the well known Sellers friction disks. The machines have sufficient power to mill the full width of the table; the cutting speed varies from 60 to 75 feet and the feed for steady work from $\frac{3}{4}$-inch to 5 inches, according to the depth of cut and other circumstances.

In Figs. 13 and 15 are shown two duplex milling machines built by the Pratt & Whitney Company, of Hartford, Conn. The tables of these machines are driven by a short screw of large diameter, engaging in a rack, which is a segment of a nut.

The duplex double-column milling machine, built by John L.

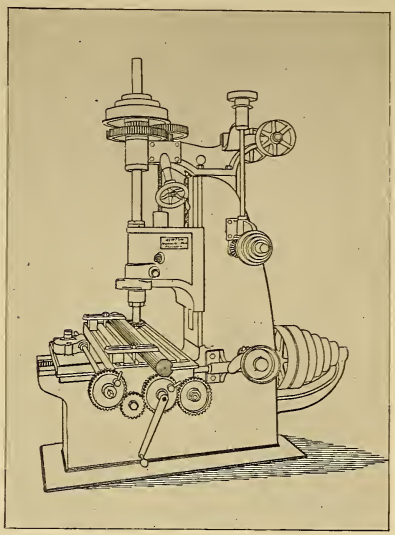


FIG. 12. CUTTING A KEYWAY.

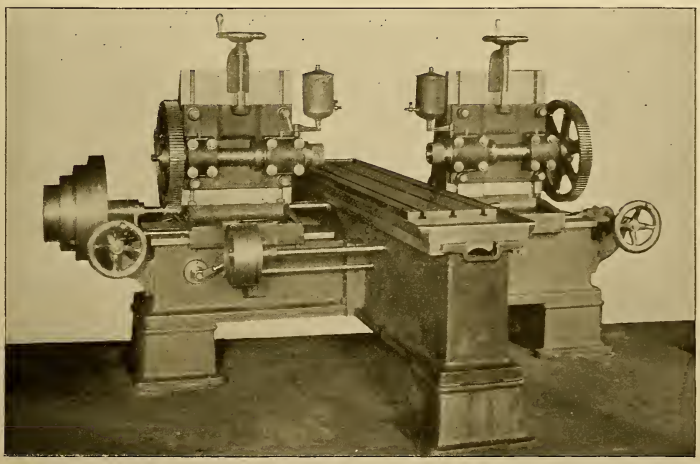


FIG. 13. A DOUBLE-HEAD MILLING MACHINE. BUILT BY THE PRATT & WHITNEY CO., HARTFORD, CONN.

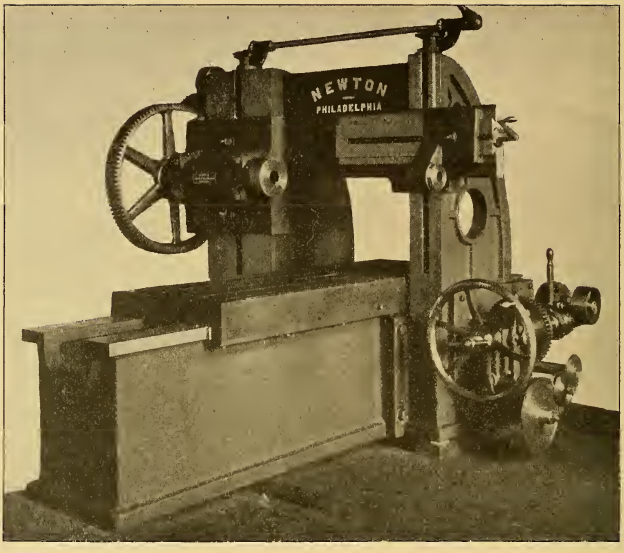


FIG. 14. PLAIN MILLING MACHINE. BUILT BY THE NEWTON MACHINE TOOL WORKS.

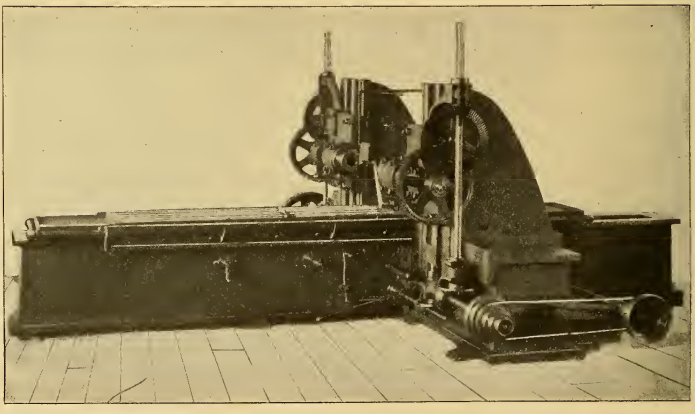


FIG. 15. DOUBLE-HEAD MILLING MACHINE. MADE BY THE PRATT & WHITNEY CO.

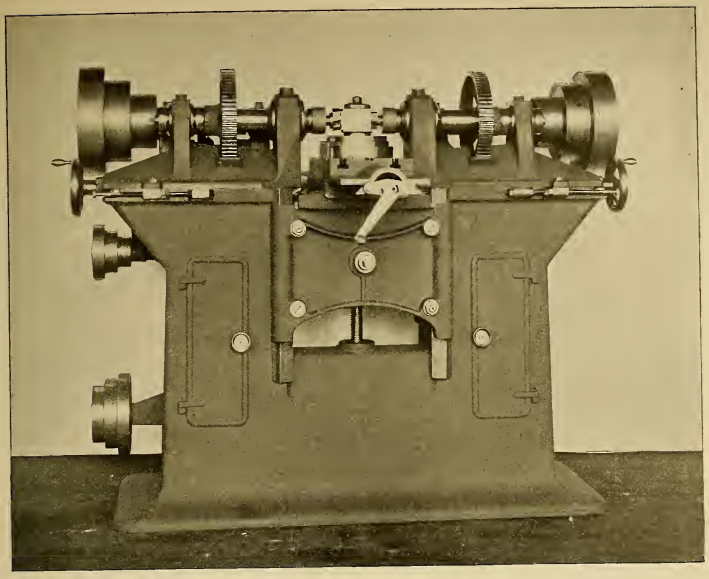


FIG. 16. MILLING MACHINE. BUILT BY JOHN L. BOGERT, FLUSHING, L. I.

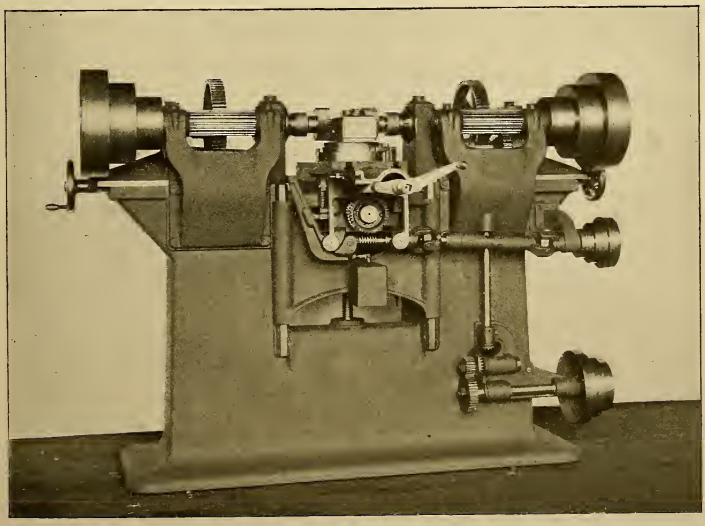


FIG. 17. REAR VIEW OF BOGERT'S MACHINE.

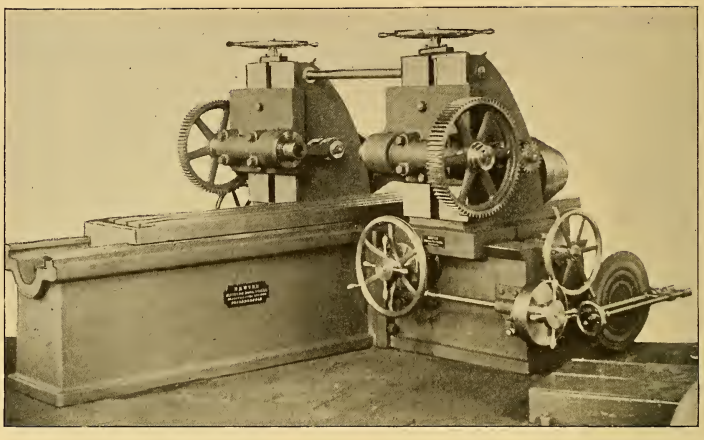


FIG. 18. A NEWTON DUPLEX MILLING MACHINE.

Bogert, Flushing, L. I., of which Fig. 16 is a front and Fig. 17 is a rear view, is a very attractive little machine on account of the originality and good engineering displayed in the design. In this case the saddle moves vertically, the heads being adjustable laterally. The difficulty of fitting the saddle to the double column is overcome by making it in two pieces and arranging the wearing surfaces so that they clamp the V's without gibs. The table is 9½ inches by about 46 inches long.

Fig. 18 shows a duplex milling machine, one of a line built by Newton. While the general design is similar to that of the plain miller, in this machine the distance between the uprights is adjustable. With this tool large butt mills are frequently used, facing the work on two sides at one operation. It is more limited in its scope than the single spindle machine, but it performs the work for which it is adapted with greater speed and accuracy (for parallel milling) than any other tool. As an example of this, may be instanced its use for facing both sides of the magnets of a dynamo. These pieces, of great weight, must be sized alike, with

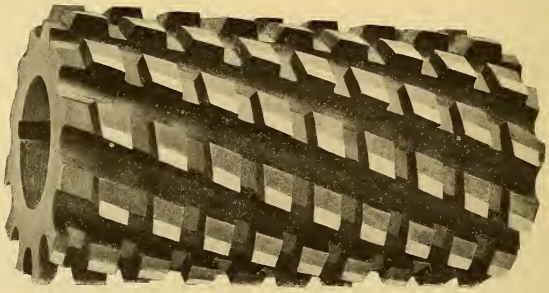


FIG. 19. A MODERN MILLING CUTTER.

true parallel sides. This would be a very difficult and expensive job for a planer. The spindles of this tool are 6 inches in diameter, and it will carry end mills 30 inches diameter. The complete machine weighs 35,000 pounds.

The cutter for use in these large machines has been worked out on the "division of labour" plan. By studying Fig. 19 it will be noticed that the teeth are so arranged in a spiral that but one or two are in action together, and that they work with a draw cut, a portion only of the cutting edge cutting at any time. This arrangement also makes a large number of short chips, and concentrates the power of the machine for a brief period upon a little portion of the cut. The Ingersoll Milling Machine Company, Rockford, Ill., make this cutter by drilling holes in a cast iron body and inserting steel cutters. Another way, cheaper and perhaps as good, is to set the steel tools in a mould, pouring the cast iron for the body around them.

In Fig. 20 we have another style, a combined vertical and horizontal spindle milling machine. It will be noticed that the vertical spindle is carried on a cross head resembling that of a planer, while the horizontal spindle is arranged on a short side cross-head. An outer bearing for the horizontal spindle is provided from the main cross-head. Both horizontal and vertical surfaces can be milled with end mills, and this, in some cases, would be an advantage, because end mills do more accurate work than side mills. Both spindles can be used at once, if desired. Fig. 21 shows a similar machine with twin vertical and horizontal spindles. Messrs. Beaman & Smith also build this class of machine with one standard removed, resembling the open-side planer, which

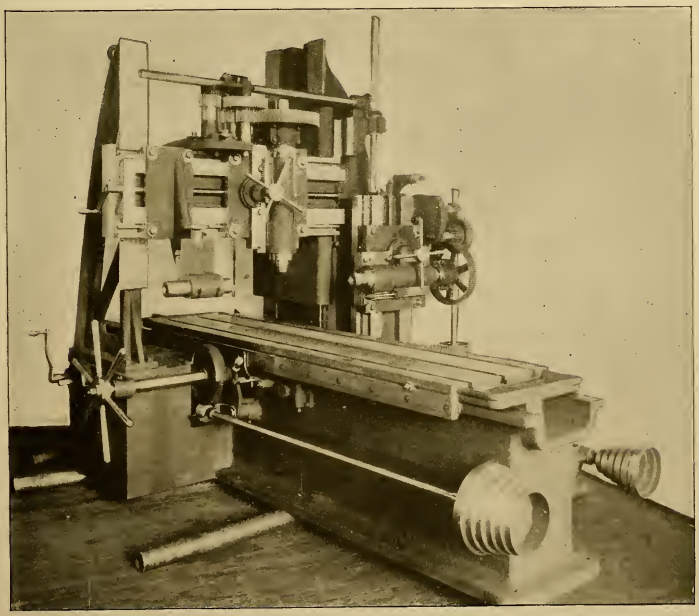


FIG. 20. COMBINED VERTICAL AND HORIZONTAL SPINDLE MILLING MACHINE. BUILT BY MESSRS. BEAMAN & SMITH PROVIDENCE, R. I., U. S. A.

would be well adapted for milling the ends of pieces too large to go between the standards.

In Fig. 22 we have a machine built by the Pratt & Whitney Company, after the designs of Professor John Sweet, and used at the works of the Straight Line Engine Company, at Syracuse, N. Y. It, too, bears a strong likeness to the planer. The vertical rotating spindle saving begins with duplication only, and rapidly increases with the amount of duplication, reaching its limit when the machine can be kept busy not only on one kind of work, but on one size of one kind. We saw an illustration of this in Eberhardt's gear cutter. It is for this reason that we find so great a variety of machines. A little volume could be written just upon the machines

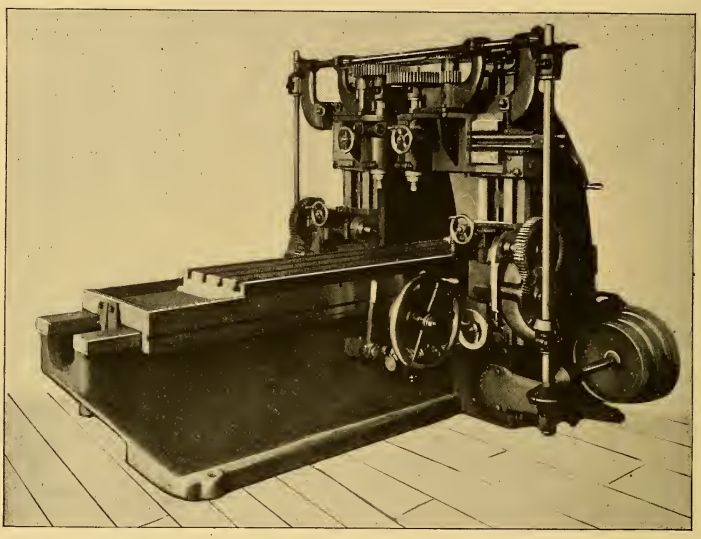


FIG. 21. MILLING MACHINE WITH TWIN VERTICAL AND HORIZONTAL SPINDLES. BUILT BY MESSRS. BEAMAN & SMITH, PROVIDENCE, R. I.

will carry drills, reamers and boring tools, besides milling cutters, the speed of the spindle being variable from 11½ to 156 revolutions. The table is driven by a rack and master gear, planer fashion; it has variable speeds and feeds in either direction. The table is 12 feet 2 inches long by 45 inches wide.

We bring this brief notice to an end out of regard for the reader's patience, although only the edges of the field have been touched upon. The milling machine is essentially a tool for duplication. There is little or no economy where the work is diversified and the number of like pieces is small. The of one of the prominent makers.

Some readers may be surprised at the modest feeds spoken of in this paper, as recent literature on this subject has been marked by the most astonishing claims on the part of some individuals in regard to milling feeds. One writer has even had the boldness to state that it was practicable to mill at the rate of 13, yes, 18 inches per minute. While we should hesitate to say that all of these writers resemble Sidney Smith's historian, who searched his imagination for his facts, it may be stated, without fear of substantial proof to the contrary, that these excessive

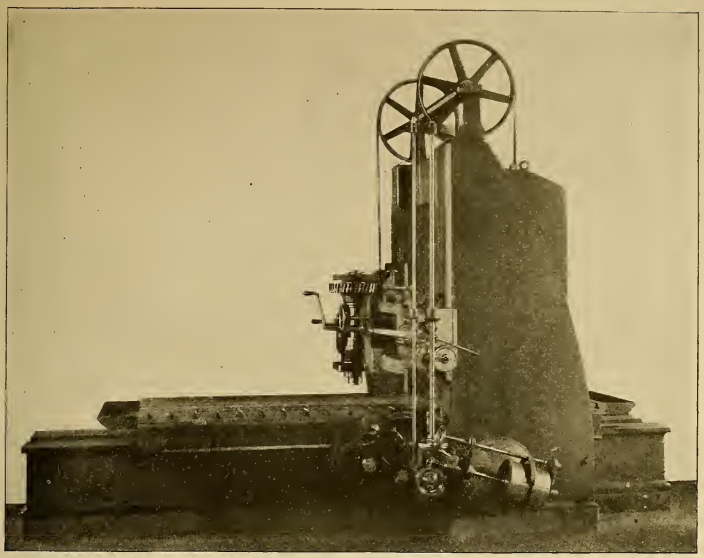


FIG. 22. MILLING MACHINE. DESIGNED BY PROF. JOHN E. SWEET, SYRACUSE, N. Y.

feeds, if actually obtained, were had under racing conditions, and are no guide for daily practice.

There has been, also, a good deal of fanciful writing upon the milling machine "of the future," which will do as great a variety of work as the planer, in as short a time as the special milling machine. But the genius who will discover it, must begin by discarding all the practice and experience of the past, for there is not to be found the slightest sign of such a tendency.

On the contrary, the best results are obtained from highly specialised machines, and, forecasting the future from the past, it is far more likely that milling machine practice will develop an infinite variety of machines, each one designed for only one service.

CONDENSERS FOR STEAM ENGINES.

By William H. Weightman.

THE question often arises in power practice,—When is it advisable to use a condenser? It may be broadly answered,—When there are ample cooling materials, fluids or mediums of any kind in sufficient quantities to be applied to a ready and economical withdrawal of the final heat from the steam after final use, to change it back to water at greater or less temperature. Under such circumstances there, of course, arises the question of obtaining, handling and operating the cooling medium without too great a cost. Al-

though water at ordinary temperatures is the prevailing cooling material, any fluid, capable of being brought into direct or indirect contact with the steam or vapour as discharged, may be employed.

If, in engine practice, this heat could be withdrawn during, and by actual, work within the cylinder, no hindrance being experienced through the presence of the resulting water, the most economical condition and use of steam in engines would be reached. Such not being the case, the condenser is connected for the purpose.

Although an expensive assistant, the fact that it develops a liberal or even a medium profit on the investment is a sufficient cause, and positive recommendation, for its use. There may, however, be additional uses to which the steam, after engine use, may be applied with ready economy, the heating of buildings, for example, of drying rooms, of water for special uses and similar objects. These may take up a portion of the surplus heat and thus reduce the pressure of the steam, but, except by the use of the condenser or some equivalent, no vacuum can be established.

The nature and latitude of the locality of the plant has considerable influence in the condenser problem. Equatorial waters at comparatively high temperatures are not as efficient as those of more northerly or southerly locations. The chemical nature, too, and the cleanly condition of the water to be used, both become a governing element in the mechanical branch of the problem. The use of the surface condenser, in preference to the jet condenser, is at all times advisable and, in fact, necessary where the waters to be used for cooling purposes contain elements and ingredients detrimental to economical operation.

The feed water heater comes in as a preferred assistant for abstracting the higher degrees of heat from the steam while on its way to a complete cooling and condensation, a clean and high-grade water being selected for use in the boilers; and a jet condenser may, by the use of lower grades of water effect the vacuum, none of the resulting waters being used in the boilers. This practice is about the best for land operations, high-grade waters only passing to the boilers, and to the cylinders as steam, and as they are not used a second time, none of the acquired defects, grease or lubricant refuse from the cylinder get into the boilers. Marine practice is similar in conditions and results, although the condensed water is necessarily retained for renewed use in preference to the salt water. Salt water is the cooling medium, and the surface condenser the preferred means. On fresh water lakes, any preferred method may be employed.

The engine itself, its capacity and ability, governs the size of condenser, high or low initial pressures calling for no greater work on the part of the condenser when expanded to the same final pressures and temperatures. The higher the initial steam pressure, the more efficient per horse-power developed will be the condenser. The use of steam in the cylinder at 150 pounds initial absolute pressure, and a hot well temperature of say 100 degrees, will give a theoretical gain of more than 19 per cent. in the condenser over the use of initial steam of 60 pounds absolute pressure.

The absolute temperature of steam at 60 pounds absolute pressure is equal to its thermometer temperature of 307.5 degrees + 460 = 767.5 degrees; that of steam at 150 pounds absolute pressure is equal to its thermometer temperature of 365.7 degrees + 460 = 825.7 degrees; that of water at 100 degrees is equal to 100 ÷ 460 = 560 degrees. Then (767.5 — 560) ÷ 767.5 = .2703 or 27.03 per cent. efficiency for steam at 60 pounds absolute pressure in the use of its heat. Again (825.7 — 560) ÷ 825.7 = .322 or 32.2 per cent. efficiency for steam at 150 pounds absolute pressure in the use of its heat. The comparative efficiency between the two is equal to 32.2 — 27.03 ÷ 27.03 = .19126 or 19.126 per cent. in favour of steam at 150 pounds.

For the cooling and condensation of the exhaust steam or vapour down to a

fixed resulting temperature of water, a fixed quantity of cooling medium will be necessary, according to its temperature. The heat has been put in by combustion; it must be taken out by absorption. The mixing of hot and cold fluids results in a mean temperature of the two, according to the total absolute heats contained. The colder the cooling medium, the less will be required; the hotter the vapour the greater the quantity of heat absorbing medium will be necessary. A pound by weight of saturated steam at different temperatures and pressures will accomplish different amounts of work according to such temperatures and pressures, but the final pressure and temperature after work is done, being the same, a like capacity of condenser will be required.

The higher the temperatures of the hot well and feed waters, and the higher that of the discharge waters, the smaller will be the amount of cooling water per pound by weight of steam and the smaller the condenser. For condenser economy, it is best to expand the steam in the cylinder to as low a final pressure as possible. Should, for instance, this final pressure be raised from 5 to 10 pounds absolute pressure, the required cooling water would be raised from the 56.339, 55.7 and 12.42 pounds above mentioned, to 66.68, 62.18 and 13.82 pounds.

About the best average conditions under which a plant can be operated is to expand the steam to a final pressure of 6 pounds in the cylinder, and this to 3 pounds in the condenser, both absolute, and discharge both the water of condensation and the cooling water at 120 degrees Fahr. This expansion into the condenser calls for a reduction of temperature of the vapour from 170.1 down to 141.6 or 28.5 degrees and an increased volume from 61 cubic feet to 118 cubic feet and consequent improved exposure, calling for from 1.5 to 2 square feet of cooling surface per horse-power developed by the engine, according to the temperature of the cooling water to be used.

Under such circumstances, water to the theoretical amount of about 19 pounds at a 60 degrees temperature will be necessary. It should, however, be increased not less than 50 per cent. in practice, and from 65 to 75 per cent. for hotter waters up to 80 degrees, so that a demand of not less than 28 to 30 pounds in temperate climates, and 30 to 35 pounds in torrid climates should be provided for. With a scarcity of water these amounts must be cooled by mechanical methods in order that they may be used again and again. For such recooling, atmospheric air has of necessity been generally used, and the immense exposures and amounts of air required, render the duty somewhat troublesome and expensive, though generally profitable.

In modern practice, a pump is used for elevating the water to a tank, from which it is sheeted or sprinkled by gravity, in what is termed a cooling tower, against a force of upward moving air to develop a maximum of contact between the two fluids. The smaller the particles or the thinner the layers of sheet water, the more efficient will be the cooling, and if a certain amount of vaporisation can be afforded, a quicker heat release will be effected, necessitating, of course, the replacing of the water lost by vaporisation, in general practice not over 10 per cent. Quite a number of these cooling towers are now in use, and have rendered it possible to make use of a condenser where previously not economical or advisable. The water to be cooled by this means, must necessarily be free from grease or dirt that will adhere to the metallic portions of the tower. It is therefore advisable to operate it in connection with a surface condenser rather than a jet condenser. Any economical device for recooling the water may of course be used.

Referring back to the comparison of mean effective pressures and the powers derived therefrom, the two non-condensing examples differ materially in their final pressures of 22 and 14.7 pounds absolute pressures. This difference represents a distinguishing feature between winter and summer practice, the extra pressure being made use of for heating and warming purposes.

Under such circumstances, while economy naturally arises from such winter uses, there is still a maximum of the heat liable to be carried off in the uncondensed steam and water of condensation. Unless, too, this water of condensation arising from the heating and warming plant is carefully saved and, with its heat, put back into the boiler, there is a good chance of steady loss. The building under such winter heating becomes the condenser in fact, although it establishes no vacuum.

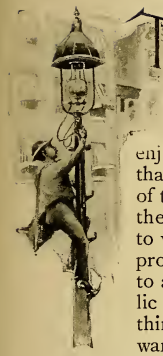
By several special mechanical contrivances, the steam pressure in the heater pipes is reduced so as to balance atmospheric pressure, and possibly to come somewhat below it, but still at the expense of some portion of the original or exhaust steam. This reduced pressure assures an operation of the heater and pipes without leakage as all pressure is inwards instead of outwards. A condenser plant, operated at the end of the heating apparatus, would act promptly and effectively in the distribution of the steam, but, in a majority of cases, would more than balance in cost any saving it could effect, except possibly by the use of the cooling tower in connection with the condenser as already cited, and unless the building is carefully piped, a short circuit of the heater steam will result to the disadvantage of some portion of the building.

In the warmer seasons of the year, with the heating of the building unnecessary, a condenser could take the place of the heater pipes and increase the efficiency and horse-power delivery of the engine, provided, however, the cost of operating the condenser be not (as it generally is in cities) too expensive in cost of cooling water. The next best thing, then, is to provide an extra ample exhaust pipe, locate it in as cool a place as possible, and rely upon it to reduce the resistance to engine operation down to ordinary atmospheric opposition.

The use of the cooling tower in cities is seldom advisable except for extra heavy horse-power plants, such as electric light and power plants, where immense quantities of water are turned over in the development and economising of power, and where small percentages of profit combine to develop immense annual savings. Even under such circumstances special care must be used in the manipulation of the steam and water, so that there shall be no deposits of dirt and oil or other disturbing elements.

LOCAL DEVELOPMENTS OF AN ELECTRIC CENTRAL STATION.

W. S. Barstow.



THE time has been rapidly approaching when the public, realising the enormous value of electricity as a commodity, is no longer willing that the few should enjoy its benefits, but demands that it be placed within the reach of the many on the same basis as the necessities of life. Unwilling to wait for the fulfillment of the prophesies of the manufacturer as to a reduction in price, the public turns to its legal advisers, thinking itself entitled to some reward for the franchise which it has granted. With the beginning of legislation begin the worries of the manufacturers, for in many cases legislation, fraught as it is with politics, kills industries in its endeavour to sustain its own popularity.

The time has already passed when new and improved machinery alone will accomplish a reduction in the cost, and it remains to the central station manager to study and plan many economies which can be brought about only through peculiar conditions of localities. As a doctor diagnoses a case before prescribing a remedy, so the central station man must study the effects of locality upon the cost of production. As the cost per unit of the product manufactured depends upon the quantity of gross business, as well as upon the generating economies in the cost of a single unit, it is necessary to take every advantage, not only of improved methods of operation, but also of new devices for utilising the product. Every company supplying current has its own peculiar conditions and surroundings, so that great care must be taken that what proves beneficial to one will not result in dis aster to the other.

Among the many Eastern American cities there are perhaps few places where the effects of surrounding are so strongly felt as in Brooklyn, N. Y., where the scattered centres of population, caused by the enrolling into one city of numerous small adjacent towns which have not yet had sufficient time to amalgamate in their business interests, offer problems of distribution uncommon to many localities.

The Edison Electric Illuminating Company, of Brooklyn, started in 1889 with a well constructed modern station and six thousand 16 candle-power lamps connected. With its only plant located in the heart of the city proper its progress was natural and success was rapidly attained, but after the cream of the business had been secured it still became necessary, as a matter of future business interest, as well as of public policy, to extend its operations into less profitable districts. This called for increased investment which would not at once pay its interest charge, and in order that the new business might not prove a burden on its receipts it became necessary to force the business along the lines already laid by providing additional uses for its manufactured product.

Thus it was that six months after the starting of the first district station the company began the development of the low-tension arc lamp. In the fall of 1890, although all low-tension arc lamps up to this time had been a commercial failure in the United States, and one of the greatest high-tension lamp

experts had stated that they would never be a success, the Edison company, of Brooklyn, prevailed upon the Universal Arc Lamp Company and the Electric Construction and Supply Company to furnish fifty sample lamps, promising that, should either be able to develop a successful lamp, an order for 500 would be forthcoming. The failure of the Universal arc lamp and the success of the Ward lamp are well known, and the popularity of the low-tension meter arc lamp can be best seen by the following table of connections of 1200 candle-power low-tension lamps to the system of the Brooklyn Edison company:

First year	500
Second year	908
Third year	1,778
Fourth year	2,600
Fifth year	3,800

Having launched its low-tension arc lamp project, the company began to look to an extension of business into new territory. The fact that the gross receipts of the company during the first three months of operation hardly equalled its operating expenses somewhat dampened the enthusiasm of the stockholders as regards the building of additional stations. With a view therefore of "pioneering," underground tie line systems were devised, and two feeders, each 10,000 feet in length, were laid to new distributing centres. At the terminals of these were placed central station switchboards from which extended the Edison underground system of feeders and mains. The value of this method of entering a new district and supplying it with current from the parent station until it had developed sufficiently to support a separate station can be seen by the following result, compiled at the end of the first year's operation.

The cost of current per unit supplied to the new district was, during the first year, only 30 per cent. of what it would have been had the same current been supplied by a separate station, necessarily operating at low efficiency. In other words, the cost of current generated at the parent station plus the loss in transmission and interest and depreciation on line, was 30 per cent. of what the current would have cost at a 24-hour separate station at the distributing end of the tie line. The difference in cost showed a profit from the very start of the new district.

This system was successful in enabling the company to start in new territories without loss to its net receipts. These districts have since that time increased in size, so as to financially warrant their being supplied from separate stations. In this way the commercial business of the company has been rapidly developed throughout the city of Brooklyn.

Up to 1892 attention had been paid only to the commercial side of the business, for all city lighting was being undertaken by a high-tension arc company. When, however, the latter announced its intention of entering the commercial field it was most natural that the Edison Company should decide to try its fortune in city lighting. With no completely developed practical system of low-tension lighting suited to the conditions of the high-tension specifications, it, nevertheless, in 1893, tendered a bid for all the street lights along the lines of its underground Edison mains. Everything was done to prevent the company from securing the contract, but low price and business-like methods prevailed and the contract was awarded, all lamps to be erected and burning in 60 days. In this time were developed, designed and put into actual commercial operation 600 low-tension street lights. With a view of holding the contract in years to come, every economy was carefully studied, and although several details in construction have been modified, yet the original system, as developed in 1892, is in operation to-day.

One of the first problems to suggest itself was the turning on and off of lamps which were in connection with continuous supplied mains. The very large expense incurred by providing attendants for this purpose can be seen at once. The lamps averaged 500 feet apart and as a twenty-minute interval was allowed between the lighting or extinguishing of the first and last lamps it was impossible for one attendant, walk-

ing 1½ miles in that time, to control more than 15 lamps. This meant the employment of 40 men to simply attend to the controlling of the lamps. This would mean an expense, at $4.00 per man, of $160 per week or $8320 per year for the lighting and extinguishing. In order to reduce as much as possible this great expense a clock switch was hastily devised for the purpose, at a total first cost of $3,600 and a total maintenance and repair cost of $2,800 annually, and this switch is still in successful operation, completely controlling at present more than eight hundred street lamps at a saving of about $5,000 annually.

The successful installation of a low-tension street lighting system and its ornamental character and good service soon gave the Edison Company the opportunity of purchasing the entire stock of its competitor in street lighting, the Citizen's Company, with its valuable overhead franchise. After all final arrangements of ownership were completed and the efficiency of the new high-tension system was increased by remodeling the Citizen's stations, it was decided to extend the usefulness of the overhead franchise by the installation of an alternating current system which should "pioneer" in those districts beyond the reach of the present Edison underground mains and tie line systems, and thus prepare the way for additional low-tension stations.

Appreciating the great advance that was being made in alternating distribution, it was necessary not only to adopt the very best system for the purpose in view but also to so modify the system that it would fulfill all the requirements of local conditions. If the system was to prepare the way for an Edison three-wire low-tension underground system, it must conform to it as much as possible from the start, so as to reduce the loss in investment when the change was made. Therefore a careful study was made of single, two, and three-phase, and mono-cyclic systems, and the two-phase system was adopted as being most similar to the Edison three-wire system in mechanical details.

In this system all feeders are four-wire and are constructed overhead. The mains in the city are underground Edison three-wire mains, a large manhole taking the place of the feeder junction box. In this manhole are placed two large transformers for not less than 300 lights each. Thus, a complete secondary three-wire distribution system is formed and to it are connected regular Edison three-wire services and three-wire system of house wiring. Mechanical meters are used and the entire secondary system is modelled and constructed similar in every respect to the Edison three-wire underground system. In fact the entire network of mains can be disconnected from the high-tension distributing alternating feeder, and connected with a three-wire low-tension feeder with no knowledge whatever to incandescent customers. Such an arrangement enables the company to install permanent underground distributing mains which, at a later day, can be at once connected to a standard Edison low-tension system, and the high-tension feeder, supplying them, can be extended into new territory beyond.

Brooklyn, unlike many neighbouring cities, has numerous small summer resorts whose period of active life lasts about four months, and these months represent the lowest output of the large Edison system. In order to secure the benefit of this class of business, at the beginning of the present year feeders, eight miles in length, were extended to these popular resorts and many profitable contracts were made. This load will equalise the work of the steam plants of the Edison company in such a way that high steam economy in the stations is maintained throughout the year. Thus, under one roof and connected to the same boiler plant, on different engines, operate the low-tension Edison city and the alternating suburban resort systems, whose combined outputs so vary during the year that they counterbalance one another.

In order to effectually reduce to a minimum the cost per unit in a generating station, it is necessary to increase the number of units output so as to les-

sen as much as possible their share of fixed charges, and also to reduce the cost per unit manufactured by station and distribution economies. The city low-tension lighting system, by making the minimum load of the station equal to its smallest unit at full load, has made it possible to operate the plants at a high point of efficiency as regards coal and labour costs. With the latest and most reliable machinery in operation, the cost of repairs has been maintained at a low figure, the sum of $450 per month representing the entire cost of all steam plant repairs to three stations aggregating 8000 horse-power operating at a maximum. The repairs to the electrical plant in the same stations average $150. All detailed accounts of operation of the company are "per kilowatt hour," so that any fluctuation in the cost of the different items of manufacture, distribution or general expenses can be seen at the end of each week and investigation made at once. While the company has, year by year, increased its efficiency in cost of product, it has not neglected the customer. At the beginning of the present year, a general reduction was made in the price of current which effected, to a marked degree, the customers of the company. The schedule of discounts is based upon the meter readings, on hours burning per 16 candle-power lamp per month, and also considers the size of the installation. In this way the company is protected in the case of poor customers, the small but good customers are satisfied, and large customers are shown the advantage of good central station service.

Thus the company by good service, a voluntary reduction in cost and price of product, and its business policy of reaching out for new business has been able to preserve the good will of the public, the keynote of the success of all corporations.

A MECHANICAL COKE-DRAWER.*

By Robert A. Cook.

AMONG the new devices for cheapening the cost of material entering into the manufacture of iron is the mechanical drawing of coke, by which the coke from bee-hive ovens is extracted with a minimum of manual labour.

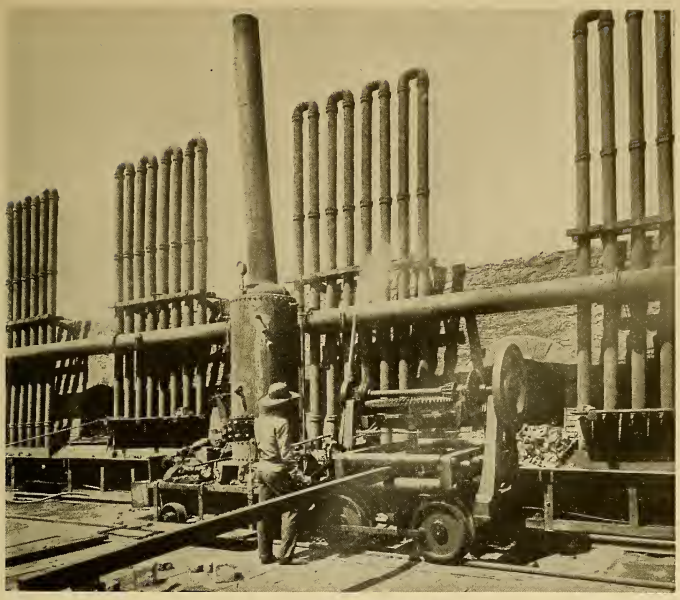
About twenty years ago, an ordinary plate-conveyor was put in use at the plant of bee-hive coke-ovens owned by the firm of Bell Bros. & Co., near Middlesboro, England. This conveyor ran close along the front of the ovens, and carried the coke to the cars. The ovens were drawn by hand, and a very great saving in cost was secured, as one man could draw and clean out twice as many ovens after the conveyor was put in use —he having no forking to do, and the coke being carried away as fast as it was drawn to the mouth of the oven.

The next step was further to eliminate hand-labour as far as possible, and Mr. Thomas Smith, of the Thorncliffe Iron Works, near Sheffield, patented in 1891 the machine for drawing coke which I here describe. This machine, the outcome of several years of experimenting, has been in successful use since 1891, and there are between twenty and thirty of them in operation at present, and others are building.

The machine, as may be seen from the accompanying illustrations, consists of a wedge-shaped shovel of proper width and thickness, connected with a steel rack of sufficient length to reach the back of the oven. The rack is supported by rolls, and guided by a device operated by a hand-wheel, which directs the shovel in the oven. The rack is driven by a pinion on a vertical shaft carrying a bevel-gear on the upper end. This bevel-gear is driven by another on the engine shaft.

The engine is single cylinder, with

* A paper read before the American Institute of Mining Engineers.



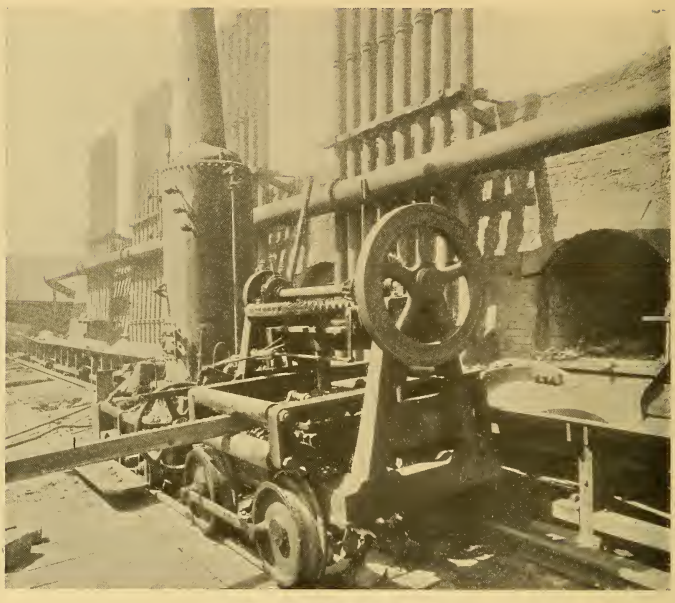
DRAWING COKE BY MACHINERY.

reversible gear, and engine and machine are mounted on a truck, which is propelled along the track in front of the oven by a worm and gear, connected by a clutch to the engine shaft. A 9 horse-power boiler, on a separate truck, is coupled to the machine and gives ample steam both for propelling and operating.

In entering the oven, the shovel runs under the coke, and as the shovel is withdrawn, the coke, dropping behind the thick end of the wedge, comes with it. The first of these machines to work in the United States was made from English drawings, by Messrs. McLanahan & Stone, Hollidaysburg, Pa., and has been in operation for the past few months at the plant of the Latrobe Coal Company, Latrobe, Pa. There is also at the same plant an English-built machine, imported from the Thorncliffe Iron Works.

The Latrobe plant, consisting of a block of thirty bee-hive ovens, is just finished and has been in operation for scarcely a month. It cannot furnish a full day's work for one drawer, as there are only fifteen ovens to be drawn daily, instead of from thirty to thirty-five, which is within the capacity of the machine. A green hand on the extractor is now drawing four 12-foot ovens per hour. Of course, the machine cannot get around the jambs, and take out the last of the coke. This is done by hand, and takes from five to ten minutes per oven.

In England, one boy operates the extractor; one man waters; one man levels the ovens and lutes up, and one man rakes out after the extractor, for a plant of sixty ovens. As the ovens of the Latrobe plant are built in double rows, parallel to the railroad, there are two lines of conveyor running to the end of the block, where a cross-conveyor running at right angles to the other two, rising at an angle of 1 to 4, takes the coke from them and elevates



ANOTHER VIEW OF THE MACHINE.

it to a chute, from which it is drawn into the car, after passing over a screen to remove the braize.

To the question, what effect this mechanical work produces on the coke, I can answer that the extractor does not break it any more than, if as much as, hand-drawing; but there is some breakage in the screen, and in looking at a car of screened coke, the fine is seen on the top while the coarse pieces run to the sides. The coke, once on the conveyor, does not move until it reaches the end and drops on to the cross-conveyor.

As regards the expense of operating, the same number of men will operate the extractor and conveyor and draw the ovens, but the cost will vary with the wages of different localities. The following men are required:—One man at the conveyor engine (unless it were run by central power plant), who could operate several conveyors and attend to oiling, etc.; one man to water the coke; one man to run the extractor; one man to rake out, and one man to lute up and level. This number of men is employed at several plants now operating in England. These extractors can be used without the conveyor, and the changes to be made in old ovens are simply to widen the oven-doors and then to lay a track in front of the ovens.

It may be of interest to know what wages are paid for drawing ovens in England in the Yorkshire district. For hand-drawing they pay 45 cents (1 sh. 10d.) per oven. This includes watering, levelling, drawing and loading on cars. The per diem wages for drawing with the extractor are, $1 (4 sh.) for engineer, 62½ cents (2 sh. 6d.) for the extractor-runner and 75 cents (3 sh.) for the man who waters; 5 cents (2½d.) per oven is paid for cleaning out after the extractor and 7 cents (3½d.) for levelling, or a total of 19.9 cents (about 10d.) per oven, against 45 cents (1sh. 10d.) for hand-drawing.

FILTERING FEED WATER FOR STEAM BOILERS.

By W. H Odell.

SOME fifteen years since, the writer, who was at that time office manager and engineer for a well known firm of water tube boiler builders, was impressed with the necessity of finding some way to prevent the formation of scale in steam boilers. Having used about all the boiler compounds at that time on the market, as well as all the devices that seemed feasible, but without entire success, it became evident not only that it was useless to attempt to keep a boiler clean by adding impurities with the feed water, but also that no mere skimming or gravity device would answer, and that the only solution of the problem must come through some positive mechanical process that would free the feed water of its impurities.

While trying to solve this problem attention was called to a proposition made by a well-known firm, who manufactured feed water heaters, to erect a feed water purifying plant along the line of one of the prominent railroad companies, and the construction of this device was watched closely from day to day in the hope that success would crown their efforts. The arrangement consisted, in substance, merely in heating the feed water up to a temperature of about 300 degrees Fahr. with steam supplied by the boiler that ran the tank pump at the pumping station, the expectation being that this heating of the water would granulate the impurities which would fall to the bottom of a settling tank, while the purified water would be stored in the water tower ready for the locomotives.

Though the scheme was a commercial failure, it was, as far as the writer knows, the first step in the series of experiments that have led up to the success of the present day, and in this light it is interesting as an object lesson. It should be stated that the mere heating of the water did throw down a large percentage of the impurities that the water contained, and there is no question in the writer's mind that, if the business had been properly managed, it would have been a success at that time.

In laying the delivery pipe from the purifier to the water tower no provision had been made for expansion and contraction, and as this pipe was about 600 feet long and subject to great changes in temperature, it was continually leaking which, of course, necessitated frequent shutting down for repairs. In addition to this the boiler and pump which had been furnished by the railroad people, were old and worn out and were a continuous source of trouble. The boiler especially was unable to carry the pressure necessary to heat the water in process of purifying to a sufficiently high degree to thoroughly granulate the impurities.

The many break-downs, and the failure to accomplish results finally disgusted the railroad company, and the whole plant was thrown out, but it was while watching these experiments that the writer became convinced that the use of a good filter in connection with the device would supply the missing link.

The next step was in the nature of an accidental discovery. A manufacturing

concern was using water for boiler feed that became very muddy after each heavy rain storm, and they were induced to purchase a closed filter through which to pass the feed water and free it from the impurities in suspension before it entered the boiler; but in place of using a common feed pump this firm used a return trap of their own construction to force the feed water into the boiler. Just how this filter and trap were connected to the boiler it is impossible to state at this late day, but by some oversight the engineer left a valve open at the close of a day's work, in such a way that all night long, or as long as there was sufficient steam on the boiler to keep up the circulation, the water passed back through the filter and was returned, refiltered, to the boiler by the trap.

Upon coming to the works on the following morning it was noticed that the water in the glass gauge was wonderfully clear and sparkling rather than of the usual milky appearance, and that the filter contained an unusual amount of impurities. Investigation soon disclosed what had been going on over night, and the matter having been brought to the writer's attention, an arrangement was soon reached by which an outfit was furnished for further experiment along this line, and a friend consenting to have the experiment tried on one of his three horizontal tubular boilers, a small plant was duly erected there, the central boiler of the nest being selected for the trial.

Examination disclosed the fact that this boiler was quite badly scaled, and that the scale was largely composed of sulphate of lime, which, as is well known, is of a hard flinty nature, very difficult to remove. A space on the bottom of the shell, and directly over the fire, was thoroughly cleaned, and as this cleaned space was directly in front of the hand hole it could be watched very closely. The filter used in this case was about 18 inches in diameter and 60 inches high, divided into upper and lower compartments. The lower compartment was nearly filled with fine sharp sand which formed the filter bed, while the upper compartment was used to wash the sand after each day's run. After that it was returned to the lower compartment, thoroughly cleaned, and the filtering process was continued.

No change was made in the feed pipes, and the feed water with all its impurities was continued to be pumped directly into the boiler; but the blow-off from the boiler was connected to the filter, after passing through which the water was returned, minus its impurities, to the boiler by the use of a steam trap, thus keeping up a circulation from the boiler through the filter and back to the boiler. The soda test showed but slight traces of lime in the water after it had passed through the filter.

Careful measurements of the amount of feed water used each day, in connection with analyses of it, showed how many pounds of impurities went into the boiler. The filter was shut off for a few minutes every day and the sand was thoroughly washed. The impurities obtained at each washing were carefully collected and dried, and it was thus demonstrated that more impurities were obtained from each day's run than the analyses showed as contained in the amount of water used, the excess, of course, coming from the boiler, and indicating that the latter was gradually being cleaned.

As the circulation through the filter was kept up for several hours after the fires were banked at the close of each day's run, the water in the boilers on the following morning was remarkably clear and sparkling and some of the employes concluded that it would be very nice for drinking purposes. A pail full was, therefore, drawn from the filter and cooled down, but they did not drink it. It had an odour that was far from pleasant and the taste was decidedly flat, and was about as deceptive as a half-ripe persimmon.

The boiler was opened each week, and the space on the shell that had been scraped clean was carefully examined, but at no time was there any indication of the formation of new scale, and after four weeks' run it was decided not only that there was no new

scale forming, but that the old scale was gradually working loose. As a matter of fact, after some four months' use the old scale was so far removed that the tubes began to leak and had to be re-expanded. There is no question that this simple process will keep any form of boiler clean when using the hardest kind of fresh water, but as for its efficiency on sea water, no opportunity has presented itself for testing it. All the indications, however, are that even here it would be a success.

The experimental plant above referred to, although intended only for one of the boilers, was so far successful that it was used on all three boilers with the most satisfactory results until the factory was burned down, and when it was rebuilt a similar device was put in and, as far as known, has given the most satisfactory results for a number of years.

The success of this experimental plant stimulated others to copy after it, and one of the most successful of these adds a small amount of soda ash to the feed water, and filters it before pumping it into the boilers. The arrangement is very successful, but, like most good things mechanical, the first cost of a plant is rather high and this causes many boiler owners to defer purchasing.

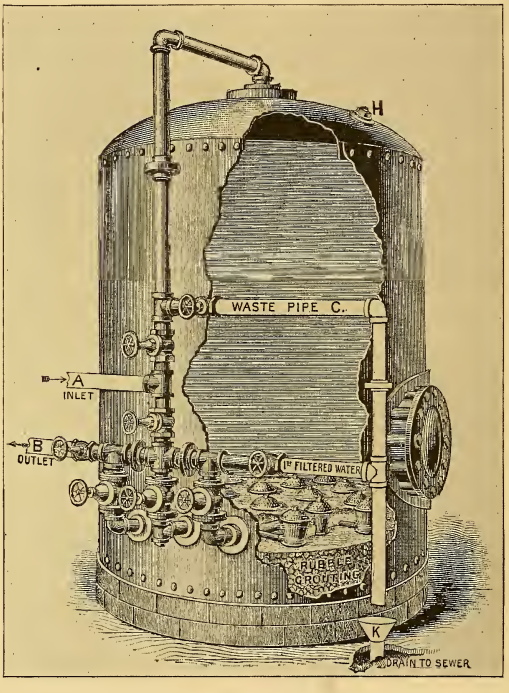
One objection to the device, and about the only one, except the first cost of fitting up, is the daily care necessary to insure its proper working. As the filter must be washed out each day to keep it in best condition, and as this washing takes from twenty to thirty minutes' time and is a hot, nasty job, some engineers do not take kindly to it, and in such cases it might prove unsatisfactory; but the incompetency, or neglect of any one in charge, should not be charged up against the outfit, as no machine will run any great length of time without attention, and it is with this as with other machines,—the better the attention, the better the results.

As there is no valid patent on this method of keeping a boiler clean, any one who is so inclined may rig up his own device. The only essential features are, sharp sand and a device that, while permitting the water to pass through after it has been filtered, will yet keep back the finest kind of sand; but as there are now on the market so many good filters (and some very poor ones) there should be no trouble in finding a suitable one. It should be made strong enough to stand the highest pressure to which the boiler would be subjected under every-day working conditions. It should also be so arranged as to permit of quickly and thoroughly washing the filter bed without undue waste of water.

Given a good filter and some suitable means of circulating the water, any boiler owner who installs a plant of this kind in a section where much lime is contained in the feed water, will find it a well-paying investment. It will not only do away with all expense of frequent cleaning of boilers and greatly reduce the cost of repairs, but it will also greatly lengthen the life of a boiler. In a section of country where the water is so bad that the life of a boiler is only from nine to fifteen months, this device has been in use on the same kind of boilers for a number of years with practically no expense for repairs. It does not need any argument, moreover, to prove that from 20 to 50 per cent. more water can be evaporated per pound of fuel with a well-arranged, clean boiler than with one that is badly scaled, and that the danger from a clean boiler is much less than from a dirty one, is self evident.

As illustrating the necessity of having the filter strong enough to stand any possible strain that might come on it from the boiler, a case may be cited in which a large filtering plant was fitted up to remove the impurities from brine, used in the manufacture of dairy salt. The filters, of which there were two large ones, were calculated to be of sufficient strength to stand a pressure of 50 pounds, but it was not intended that more than from 20 to 30 pounds pressure should be carried on them, and they were fitted with gauges to indicate the pressure. The scheme was to have a jet of steam of 200 pounds

pressure strike the brine in the form of a fine spray in a closed tank and thus throw down the impurities, which were to be removed in passing the brine through the filters. The tank in which the steam and brine came in contact was made strong enough to stand the boiler outlet could carry it off, the pressure would increase on the filters, but this increase of pressure would be gradual, as the entire contents of the filters would have to be increased in temperature to correspond with the increased pressure. However, when the writer saw this ar-



A FILTER MADE BY THE NEW YORK FILTER CO., NEW YORK.

pressure, and, as a matter of fact, the pressure on the boiler and tank was the same. The brine after this treatment was led to the filter, the pressure on which was controlled by a series of plug cocks on both the inlet and outlet pipes to and from the filters.

It will be understood that in case the outlet cock from the filters should become partly clogged up, so that the hot brine, with 200 pounds pressure behind it, should enter the filters faster than the rangement he concluded at once that it was a very dangerous one and urged that a safety device should be attached to prevent the possibility of an explosion in case the man in charge, who was supposed to regulate the pressure on the filters by manipulating the inlet and outlet cocks, should become careless or negligent; but as the writer had no authority to enforce his suggestions his advice was ignored under the plea that as they had operated the apparatus

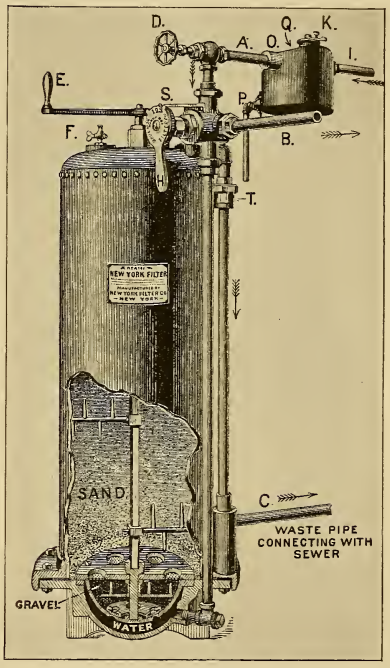
some three months without trouble they "guessed they could continue to operate it without assistance from outsiders."

It was but a few days before the expected did happen. The pressure, in some way, accumulated on the filters and they exploded, killing several men, wrecking the place and eventually causing a loss which brought the company to bankruptcy. In addition to this, what at one time promised to become a valuable industry was blotted out of existence.

While this case is referred to primarily to show the necessity of making the filters of ample strength to stand any pressure to which they might be subjected, it might also be referred to as an illustration of the efficiency of the sand filter in separating the impurities by merely first subjecting the brine to the action of heat. As stated above, the brine in the form of spray was brought in contact with a jet of saturated steam and this simple process which was performed in a rather crude and inefficient manner, was sufficient to separate about 96 per cent. of the bittern, so that it was possible for the filters to get hold of and retain it. It is quite possible that even a greater percentage of the impurities could have been separated if the device had been more carefully operated.

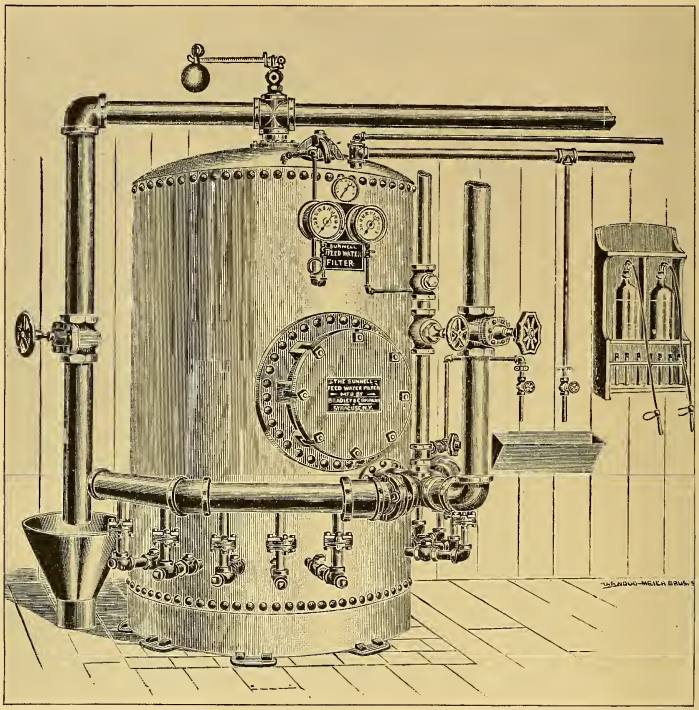
As to the cost of operating a plant of this kind, it may be said that to the heat lost by radiation, which can be computed on the surface exposed, we must add the cost of the soda ash if any be used. While the process described will keep a boiler clean without the use of soda ash, yet when the extremely low cost of the latter is taken into consideration, it would seem advisable to use it. Experience has shown that it requires a trifle less than one grain of soda ash to precipitate one grain of lime sulphates and chlorides and it is merely a question of the number of grains of impurities contained in an amount of water sufficient for a day's run, to determine the cost of the necessary amount of soda ash. Under ordinary conditions about ten cents per day will pay the cost for a 500 horse-power boiler plant, but just what the cost of running such a battery of boilers on bad feed water is it is difficult to compute.

It may not be out of place to say in this connection that an effectual



ANOTHER FORM OF FILTER MADE BY THE NEW YORK FILTER CO.

and inexpensive way of proving the efficiency of sand as a filtering material, and, at the same time, providing a good filter for domestic purposes is to get a piece of galvanised rain water leader pipe about 40 inches long and 4 inches in diameter. Through one end fasten a wire from which to suspend it. Over the bottom end



THE BUNNELL FEED WATER FILTER. MADE BY MESSRS. BRADLEY & CO., SYRACUSE, N. Y., U. S. A.

fasten four thicknesses of cheese cloth to hold back the sand. Get some clean, sharp, and fine building sand, which first wash thoroughly to remove any clay that it may contain. Then fill to within about six inches of the top. Pour the water to be filtered on top of the sand and wait about a minute for the results.

This simple filter is so effectual that it removes all trace of algæ, which give that objectionable fishy taste to some waters that in all other respects are acceptable, and, surely, when a filter is sufficiently effective to remove an odour it is about all that can be asked for, or expected for the price.

As a matter of fact, this simple sand filter is more effective and satisfactory in every way than some of the domestic filters that are on the market at relatively very high prices.

To what has thus far been said it may be interesting to add a few illustrations and particulars of several filters which are now in satisfactory use in the United States. The illustration on page 368 shows a vertical form constructed by the New York Filter Company, of New York, and a brief description of this will cover the essential features of almost all.

The tank is filled with sharp, fine sand up to the line of rivets connecting the bumped head. The water to be treated enters at *A* and, with the proper adjustment of valves, passes to the top, then slowly down through the sand to the

cone valves cemented into the bottom, and thence up to the outlet pipe *B* to the boiler or wherever wanted.

As the impurities lodge on the top surface of the sand it becomes necessary to frequently wash them out, or the whole device would become clogged up. This washing is easily and effectually done by merely severing the flow of water through the filter-bed by the proper adjustment of the inlet and outlet valves as will readily be suggested by an examination of the valves and piping.

By closing the valve directly over the inlet pipe *A* and on the outlet pipe at *B*, and opening the valve that connects the inlet and outlet pipes, and also the valve on the waste pipe, the water will flow up through the filtering material, carrying off all the impurities through the waste pipe *C* to the sewer.

It will be noticed that the cone valves in the bottom of the filter are attached to three lines of piping, each pipe being provided with a stop valve outside the shell, and when washing out, it is advisable to have the entire flow of wash water go through each valve separately. This permits of the washing of about one-third of the filter-bed at a time and gives the sand a scouring action that is very effectual in cleaning it of every particle of impurities, and restoring it to its original condition. The intervals between these washings will depend in a great measure on the amount of impurities contained in the water that is to be filtered, but, on an average, about once each day is sufficient.

On page 369 is shown a smaller filter made also for household purposes by the same company. The cut shows a coagulating tank connected to the filter. The unfiltered water enters this tank at *I*, and, after passing through it, enters the top of the filter, passes down through the sand and is received in the basin at the bottom of the tank from which it is piped up the outside of the filter tank to the pipe marked *B*, which may be connected to the boiler or the house service. The arrows plainly indicate the direction of the flow of the water which is controlled by the operating valve, the handle of which is marked *H*.

To wash the filter, this handle is shifted so as to reverse the current of water which then enters at the bottom of the filtering bed, passes up through the sand and out through the pipe marked *C* to the sewer or waste water pipe. As the water begins to flow up through the sand the crank *E*, that connects with an agitating shaft, should be turned slowly. This thoroughly agitates and scours the sand, loosening such impurities as have adhered to it, so that they may be carried out with the flow of the water to the sewer. A sight glass at *T* shows when the water runs clear, or when the sand is thoroughly washed, and the handle *H* is then put back to its original position, and the process of filtering is resumed.

To fill and make use of the coagulating tank, all that is necessary is to close the small lever valve *K*, remove the cover *Q*, and drain out the solution by opening the waste valve *P*. Then fill the tank with coagulant material, generally crystal or lump alum, fill up the interstices between the lumps of alum with water, replace the cover, open the small lever valve *K*, and go ahead. The amount of coagulant to be used must be determined by experience, but generally, if the lever is placed at the first hole in the dial, it will be found sufficient.

The cut on the opposite page is an exterior view of what is known as the Bunnell filter. Its interior construction and operation is virtually the same as that of the New York Filter Company and is introduced here principally to show the arrangement of pipes to introduce a soda solution into the water before it is filtered, the makers claiming this to be a desideratum as it helps to separate or granulate the impurities, so that the filtering material can do more effective work.

While the external appearance of the various makes of filters on the market are much the same the real point of difference is in the devices for holding back the sand while permitting the water to pass through freely.

STEAM TURBINES.

Their Advantages and Disadvantages.

By Professor John H. Barr.

THE last few years have witnessed a revival of not a little interest in the earliest type of the steam engine, known in its modern form as the steam turbine. Until quite recently, these early devices were looked upon as mere mechanical toys, but, of late, they have acquired a new interest, owing to the similarity between some of them and certain forms of the steam turbine now on the market.

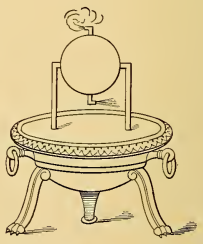
The first steam motors of which we have any record were of the reaction type. In the celebrated engine of Hero of Alexandria (200 B. C.), the steam generated in the lower vessel was conducted by means of a hollow trunnion to the pivoted sphere, from which it escaped through the bent outlet pipes to the atmosphere. The escape of this steam caused the sphere and bent tubes to rotate by reaction.

Branca's engine (1629), shown on the next page is very suggestive of the modern turbine; it especially resembles the De Laval construction. This old device is simply a boiler with a steam pipe terminating in a nozzle from which the escaping steam impinges upon the vanes of a properly supported wheel.

Both of the preceding illustrations are drawn from the "History of the Growth of the Steam Engine," by Dr. Robert H. Thurston, to which those interested in the development of the engine are referred. The scope of the present paper does not permit any extended historical sketch.

An attempt will be made to discuss some of the principal advantages and disadvantages of rotary engines in general, and of the turbine form of such engines in particular. Most engines are employed to produce rotation of a shaft, and the manifest advantage of an engine of the rotary type, on the score of simplicity of transmission, has led to innumerable attempts to displace by it the standard engine with its reciprocating piston, its connecting rod and crank. In point of connection with the driven shaft, economy of space, and balance at high rotative speeds, the rotary engine has strong claims upon the attention of inventors.

Rotary engines of the piston type



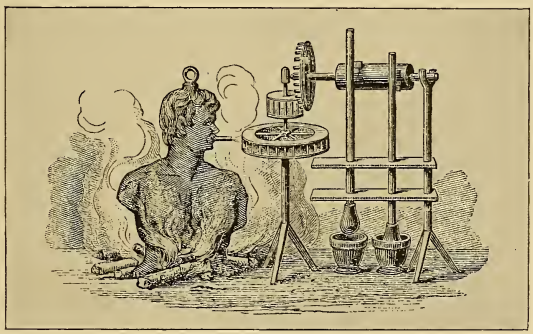
HERO'S ENGINE, B. C. 200.

have, however, never met with general success, the great obstacles having been encountered in maintaining steam tight piston packing, in constructing practicable valves, and in avoiding excessive friction. These engines retain the char-

actersitic defects of the reciprocating engine, such as cylinder condensation and re-evaporation, clearance losses, and defective steam distribution, and have usually exhibited these faults in an excessive degree.

The steam turbine has many of the mechanical advantages of other rotary engines, while it is absolutely free from the most serious avoidable waste of the piston form of engines, viz., cylinder condensation and re-evaporation. In any of the piston engines, either reciprocating or rotary, steam enters the cylinder at a temperature corresponding to the initial pressure, and is exhausted from the working chamber at a lower pressure and temperature. The internal surfaces of the cylinder tend to take the temperature of the entering steam during the admission period, thus abstracting heat from the steam and causing a corresponding amount of condensation. During the exhaust period the temperature of the steam is below that of the confining walls, and the metal then gives up heat to the escaping steam. With a sufficiently long exposure to the steam, the temperature of the walls and of the steam would become the same.

In practical operation, the time of continuous exposure of the walls to either the higher or the lower temperature is so short that only a small portion of the mass of the cylinder is affected by this periodic variation of temperature, and this portion of the metal does not undergo the full range of temperature due to the working range of steam temperatures. However, the effect of this method of operation, resulting in a condensation of steam during the early portion of the cycle, and a re-evaporation of it during the latter part, introduces the most serious loss, next to the necessary thermodynamic loss, experienced in the operation of the steam-engine. This loss is greatly aggravated by the presence of moisture, either carried over from the boiler, or due to the initial condensation in the engine.



BRANCA'S STEAM ENGINE, A. D. 1629.

If steam could be kept perfectly dry durnig the early period of the cycle, the loss would be greatly reduced, as dry steam, or a gas, is greatly inferior to wet steam in heat-conducting capacity.

If either the fluid or the material of which the internal surfaces of the cylinder are composed could be a perfect non-conductor of heat, this thermal loss might be avoided. With highly superheated steam, and with gas engines, the transfer of heat between the working fluid and the cylinder walls is thus greatly retarded, but is not absolutely checked.

Numerous attempts have been made to line the cylinder with enamel or

some other coating of inferior conductivity, but this expedient has never passed beyond the experimental stage. The effect of internal condensation in the cylinder is quite analogous to leakage past the piston. In the one case, heat escapes from the working to the exhaust side of the piston, that is from the boiler to the exhaust, without useful effect, by entering the walls of the cylinder during the early part of the cycle, and by emerging during the latter part. In the other case, heat escapes from the boiler to the exhaust by direct flow, in the steam, around the piston packing. In both cases the heat thus wasted in one cylinder may be usefully applied in the succeeding cylinder of a compound engine.

In addition to the methods for reducing cylinder condensation which have been indicated above, other expedients have been adopted for a similar purpose. Compounding has been highly successful by reducing the temperature range in any one cylinder, for a given total range between boiler and exhaust. High rotative speed tends to decrease the loss, other things being equal, by reducing the time of exposure of the walls to temperatures either above or below that of their internal surfaces. Steam jacketing is often an effective remedy by keeping the steam which passes through the cylinder more nearly dry. While all of these methods have done good service they, at best, afford only relief; none of them effects an absolute cure.

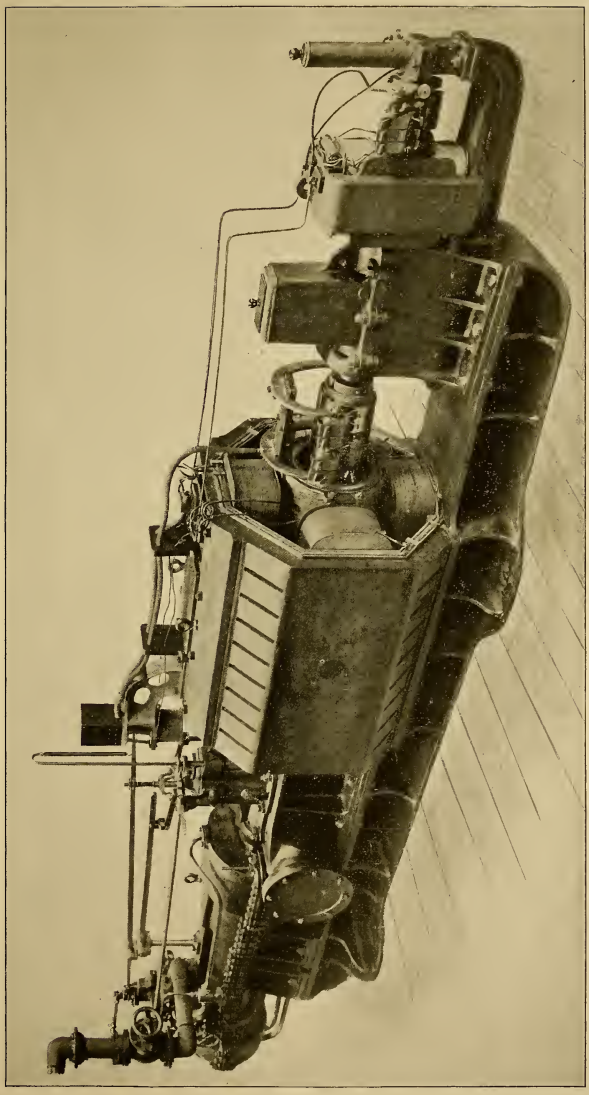
The steam turbine is entirely free from any loss corresponding to that treated in the preceding discussion, inasmuch as it has no surfaces exposed, in regular operation, to a periodic change of temperature. So far as the writer is aware, it stands alone in this exemption, as there is no other form of heat engine in which this source of loss is entirely eliminated. The phenomenon of cylinder condensation has received the closest study for many years from eminent scientific investigators and engine designers. Constructors have added the complications incident to two, three and even four cylinders, with their separate pistons, valves, and gearing; they have provided steam jackets, entailing extra cost of construction and provision for drainage; and have encountered the difficulties of lubrication, added wear of packing, and danger from burning out of superheating surface.

Compounding introduces other advantages than a reduction of cylinder condensation, but so far as this consideration is concerned, to what purpose are all of these costly expedients applied? Simply to partially overcome the waste, to modify, but not to eliminate, the evil!

The compact, modest little turbine, consisting essentially of a revolving wheel and its supporting frame—but two pieces, kinematically, and no machine can have fewer parts,—in the abstract the very acme of simplicity in machine construction, and with all the advantages ascribed above to the rotary engine, is the only form of heat engine offering a complete solution of the cylinder condensation problem. This is, indeed, striking, and is alone a sufficient reason for deep interest.

In spite of all that has been said, the steam turbine designer has his own peculiar difficulties with which to contend. Among the greatest obstacles to commercial success of the turbine are those due to the extreme high speed required for efficient operation; to leakage of steam; to friction, and to balancing the rotating parts.

The requirements of electrical machinery have been a powerful stimulus to the development of the high-speed engine, largely because of the troublesome intermediate machinery of transmission, made necessary in driving the earlier forms of dynamo from low-speed engines. The multi-polar dynamo has filled the gap between the Corliss engine and the electrical generator, to a great degree, for large units, although the result is a ponderous combined machine, expensive in money and in floor space. The high rotative speed of the steam turbine presents a complementary difficulty in the transmission machinery for "gearing down" to the delivery



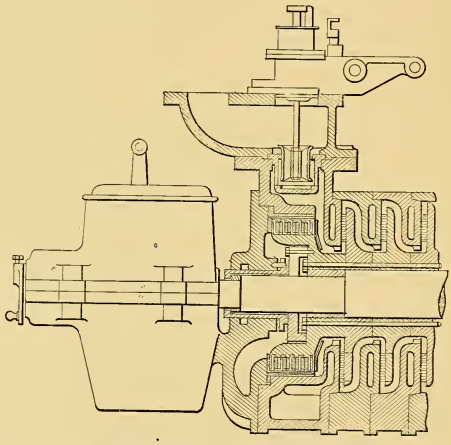
A 350 KILOWATT STEAM TURBINE ALTERNATOR. BUILT BY MESSRS. C. A. PARSONS & CO. NEWCASTLE-ON-TYNE, ENGLAND.

shaft. While such gearing down may not be an absolute requirement for driving a dynamo, the absence of satisfactory means of reducing the speed must greatly limit the application of the turbine. Anything effecting an ideal solution of this problem is yet to be produced.

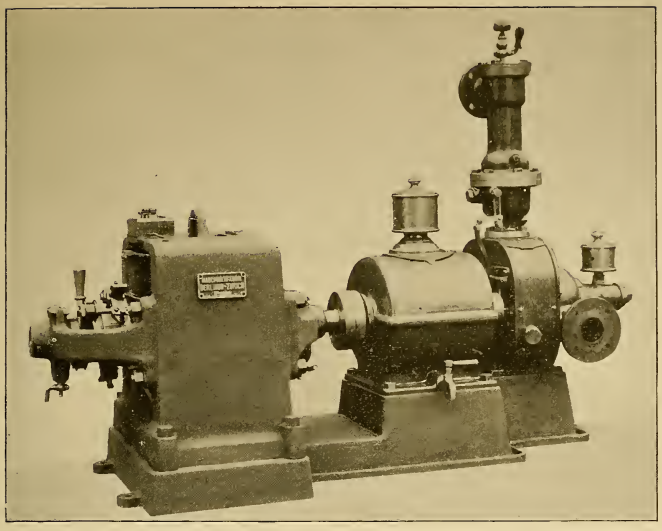
The beautifully constructed twisted gears used in the De Laval turbine have justly called forth high admiration, not unmixed, however, with some grave misgivings. They are very quiet for gears at such high speeds, the pinions running as high as 25,000 revolutions per minute in the small sizes, and the larger gears at one-tenth this speed, but they are not noiseless, and are of questionable efficiency under average running conditions. The speed factor of the energy delivered by steam turbines is so high, and the force factor is so small, that even a slight frictional resistance to rotation of the motor shaft is seriously detrimental, if not fatal to good economy. The revolving disc, ring, or whatever supports the working vanes, must move, relatively to the fixed guide vanes or nozzles, with very little or no rubbing friction.

One particular turbine, rated at 10 horse-power, has a wheel 8 inches in diameter, which runs at about 25,000 revolutions per minute. This corresponds to a peripheral velocity of over 52,000 feet per minute. To transmit one horse-power at this speed requires a tangential force at the rim of only $33{,}000 \div 52{,}000 = 0.635$ pounds, or 6.35 pounds to transmit 10 horse-power. It is evident from this that a slight friction at, or near, the rim of the wheel will seriously impair the mechanical efficiency.

Three of the leading steam turbines are the Parsons, the Dow, and the De Laval. The first two of these expand the steam gradually from boiler to atmospheric, or condenser, pressure in passing through the turbine, by action upon a series of vanes. A description of the Parsons turbine, with a report of actual tests, was given in CASSIER'S MAGAZINE for December, 1892, by Professor Ewing. One of the illustrations here reproduced shows a section through three of the six series of revolving discs. These working discs carry annular vane rings between which are placed corresponding fixed guide vane rings. The steam enters near the shaft at the left, and flows radially outward,



A SECTIONAL VIEW OF THE PARSONS TURBINE.



A DE LAVAL STEAM TURBINE DYNAMO. BUILT BY THE OERLIKON MACHINE WORKS, ZURICH, SWITZERLAND.

alternately acting upon the working vanes and being deflected by the guide vanes. The areas of the passages are increased, successively, to provide for the expansion of the steam, which is finally discharged at a low pressure into a condenser.

The Dow turbine has a single revolving disc with annular rings, similar to those of the Parsons, upon both of its faces, each ring alternating with a fixed ring in which the guide passages are formed. In this turbine the two streams of steam flow outward "in parallel," passing to a common exhaust chamber at the outside of the casing. In the Parsons form, the sets of annular vanes are "in series," the steam flowing outward through each set in succession, but flowing axially with reference to the machine as a whole, except for the last set in which the steam is divided, flowing in parallel, very much as in the single pair of passages of the Dow form.

In both of these forms the reduction of pressure as the steam passes through the turbine is gradual, and any leakage resulting in the flow of steam around, instead of through, the working rings is a source of loss. It is thus, for the best results, essential to have steam tight joints between the fixed and moving rings, while actual metallic contact, with its resulting frictional resistance, is very detrimental as pointed out above. That the exceedingly difficult task of securing a multitude of tight, yet free, joints has been skillfully accomplished appears from the wonderful performances which are vouched for by high authority. That the requirement has been certainly met in the various forms is not so evident, for other investigators have reported much less favourable economy, and it seems quite probable that friction or leakage in the latter instances may account for the unfavourable showing.

The De Laval design represents a radical departure from the lines followed by the constructors of other turbines. A single set of vanes, cut through the revolving disc near the outer edge, is used with one or more nozzles for con-

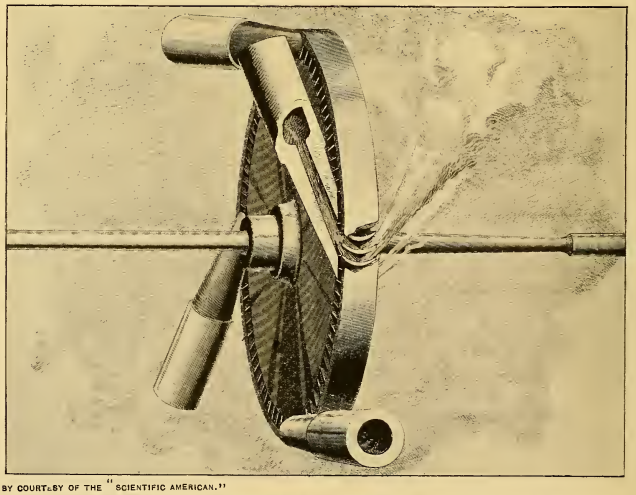
ducting the steam to the vanes. The wheel and nozzles—removed from the casing—are shown in the illustration on this page, taken from the *Scientific American.* The illustration very cleverly explains the operation. The steam is expanded down to the exhaust pressure within the nozzles before acting upon the wheel. As the pressure is equal on both sides of the disc, there is no tendency to leakage, and one of the steam turbine difficulties is thus eliminated by a most original method. The free expansion of the steam within the nozzle converts the energy due to its initial pressure into kinetic energy. The particles of steam thus impinge upon the vanes at a very high velocity, and the operation is that of an impact motor, as in the well-known Pelton water wheel.

The balance of a wheel at such high rotative speeds as are attained in turbine practice is a matter of much importance. It is practically impossible to so construct the wheel that it will have a perfect running balance, that is, so that the centre of mass will coincide with the centre of figure.

In the Parsons turbine the bearings consist of several bushings fitted over each other loosely enough to permit the introduction of films of oil between them. These layers by being reduced in thickness on the side of the resultant pressure at any instant, allow the wheel to revolve about an axis not exactly coincident with the geometrical axis.

The De Laval turbine disc is mounted upon a long slender shaft, which springs enough laterally to allow the wheel to rotate about an axis outside of its normal geometrical axis. The continual flexure of this shaft produces a constant change of stress, alternating between an equal tension and compression fibre stress.

From what is known of the effect of such alternating loads, it will be seen that this action, unless quite moderate, may result in final rupture. At 17,000 revolutions per minute, there are over 1,000,000 alternations of this stress per hour, and we need not be surprised if such shafts frequently have short life. In connection with this it may be of interest to quote a paragraph which appeared a few months ago in an English paper. It reads as follows:—



BY COURTESY OF THE "SCIENTIFIC AMERICAN."

A SECTIONAL VIEW OF DE LAVAL'S STEAM TURBINE, AS BUILT BY G. DE LAVAL'S STEAM TURBINE WORKS, STOCKHOLM, SWEDEN.

"The De Laval impulse engine is making way in France. During twelve months past the French company have built thirty-nine plants for electrical work, fitted with the turbines, some of them being of 300 horse-power. From a private letter we learn that a good many of the flexible spindles on which the wheels are mounted, break, and this is not to be wondered at. This is a fad, we may call it, of the inventor, and we think of no importance whatever, because other more durable mechanical expedients will answer the same purpose. It is nearly impossible to perfectly balance a body to run at a rate of ten to fifteen thousand revolutions per minute, and the doctor mounts his wheels on slim shafts that will bend, and thus permit the wheel, like a spinning top, to assume a theoretical centre of gyration. Any kind of yielding support will do this. An engine or wheel made here by Mr. W. A. Doble was fixed on an overhanging shaft, which is in effect the same thing, but the true way seems to be in providing a movable bearing, as in the case of centrifugal extractors."

In conclusion a few results of trials will be given to indicate what has been accomplished with the steam turbine. Professor Ewing's report (1892) on trials of a Parsons turbine giving an electrical output of about 100 Board of Trade units, with steam pressure of about 100 pounds to the square inch, and condensing and with moderate superheating (about 30 degrees), shows a steam consumption of about 20 to 20.9 pounds of steam per electrical horse-power per hour. He estimates this as equivalent to about 15.1 to 15.7 pounds of water per indicated horse-power per hour. The water rate at half load is reported at from 30 to 32 pounds per electrical unit per hour, or 22.4 to 23.9 pounds per electrical horse-power per hour.

A report of trials made upon a De Laval turbine at Stockholm by Professor Cederblom, with Messrs. Anderson and Uhr, was presented at the World's Fair in 1893. This turbine is credited with delivering 63.7 effective (brake) horse-power, with a water rate of 8.95 kilograms (19.7 pounds) per delivered horse-power per hour. The steam pressure was from 108 to 122 pounds per square inch, and the exhaust pressure was equivalent to a vacuum of 27 inches of mercury.

At one of the recent meetings of the American Society of Mechanical Engineers, Professor W. F. M. Goss reported on some trials of a small De Laval turbine, which used, at the maximum load of 10.33 brake horse-power, 47.8 pounds of steam per effective horse-power per hour. In the discussion on this paper, Mr. J. W. Lieb, Jr., general manager of the Edison Electric Illuminating Company at New York, said:—

"It may be of interest to learn that in a few weeks the Edison Electric Illuminating Company, of New York, will have in operation at one of its stations two 300 horse-power De Laval steam turbines with attached dynamos. These turbines were built by the Maison Breguet, Paris, and were ordered under guarantee to comply with the following specifications:—

"Each 300 horse-power turbine is to drive two Desroziers dynamos, each of 100 kilowatts (133 horse-power) capacity. The turbine shaft is to run at 13,000 revolutions, driving at a speed of 1,300 revolutions, by means of helical gearing, two dynamo shafts situated on either side of the turbine shaft. * * * If the turbines are built to be operated either condensing or non-condensing, as a mongrel type, with a steam pressure of 10 kilos per square centimetre (142 pounds per square inch) at the throttle, and with a vacuum of 65 centimetres at the condenser, the steam consumption per brake horse-power is guaranteed not to exceed 8½ kilos (18.7 pounds); with a free exhaust the steam consumption is not to exceed 16 kilos (35.2 pounds). If it should be contemplated to operate the turbines ordinarily with a condenser, the guaranteed steam consumption will be reduced to 7½ kilos (16.5 pounds) per brake horse-power. In this case the turbine disc would have a diameter of

0.75 meter (29 inches), instead of 0.50 meter (19⅝ inches) for the mongrel type."

While it does not seem probable that the steam turbine seriously threatens the standard reciprocating engine for general power purposes, yet the results already attained, indicate that it must be reckoned with, in its proper field, at no distant date.

It is rumoured that these turbines have since been tested, and have shown an economy of about 17 pounds per horse-power. Under just what conditions these tests were made the writer is not informed.

THE INSURANCE OF ELECTRICAL PLANTS.*

By R. H. Pierce.

ONE of the most serious problems to the owner or manager of a central station is the reducing of the fire hazard to a minimum. The problem of safety is the real question, and when this is solved we at the same time solve the problem of insurance.

In the opinion of the writer, the insurance question which the central station manager has to answer is simply the question of making his plant insurable. This may appear to be a radical view, but I believe it is logical. A large proportion of existing plants were installed at a time when the electrical manufacturers and electrical constructors did not understand what materials and methods should be used in order to secure safety; and finally, and worst of all, many plants have been installed by companies or individuals whose only thought was to get the largest price for the cheapest installation, leaving the unfortunate station owners and managers to wrestle with the question of safety, as well as of reliability and economy. But however serious the question may be, it must be met and if attacked in the right way, the solution may not be as difficult as it at first appears.

The results of a central station fire are twofold:—First, there are the losses due to interruption of service; and second, there is the loss of plant. I have placed the losses due to interruption of service first, as these must be considered whether we consider the question of insurance or not. The interruption of service for any considerable time, or a decrease in patronage due to irregular or uncertain service may, and often does, mean a difference in revenue, which is the difference between a profit and a loss in the operation of the station, and operating a station at a loss is worse than losing it.

The way to secure safety and reliability is to have proper construction and proper care, protection and attendance. The proper methods for securing safety are laid down in the rules and requirements of the National Board of Fire Underwriters and are well known to all engineers and constructors of any standing.

The question of insurance can be met in three ways:—First, by insuring in responsible and reliable insurance companies; second, by the formation of a mutual company by central station owners; third, by securing the maximum safety through the use of proper construction, care and fire protection, and taking the chances of a fire loss.

As a general proposition the only reasonable course is the first one indicated, namely, the insuring in responsible and reliable companies. The plan of forming a Central Station Owners' Mutual has been "weighed in the balance and found wanting." Theoretically, it may be possible to form such a mutual company, but it would be an additional burden to the central station business, which, I take it, has trouble

*From a paper read before the Northwestern Electrical Association, U S.

and problems enough to face already. If fire insurance is a legitimate business, —and it appears to be as legitimate a business as electric lighting—then we may as well assume that the insurance people know their business and that the competition between insurance companies will produce as low a rate as could (with equal protection) be given by a mutual company. The third method mentioned, of securing maximum safety and then taking the chances, may be the best in some, but only in very special cases. If the central station plant is so designed, installed and operated as to reduce the fire hazard to a minimum, insurance companies will ask a minimum rate of insurance which, in most cases, will be so small as to be no burden to the owners. Discarding then the two plans just mentioned, we are brought to the first plan of insurance in reliable companies. Accepting this as our line of action, the problem now is to so install and operate our plants that the hazard is reduced to a minimum or at least to a point where further improvements would increase the cost out of proportion to the additional safety secured.

The great problem is, as I have said, how to best secure safety. Competition in the electrical manufacturing and construction business has not led to increased safety. On the contrary, it has led to cheapness in both appliances and methods, and cheapness does not mean safety. On the other hand, we must not think that we must be extravagant in order to have safety. The use of proper methods of construction and of intelligence and care in operation are what is most necessary to secure safety.

If, however, we cannot look to the electrical companies for protection, to whom shall we look? Who should judge of what is necessary for safety? Who has devoted most time and thought to this subject? The National Board of Fire Underwriters beyond a doubt. Whether we insure or not, the regulations of the underwriters are to-day the best, and, we may say, only guide to safety. Their requirements can of course be improved, but the insurance people are ready and anxious to receive suggestions from all engineers and central station men. I sincerely believe that a study of the requirements of the underwriters, and a free discussion of their merits by central station men and engineers is the one thing that will lead to an understanding of the insurance question and will eventually lead to an understanding between owners and insurance companies, which will be mutually satisfactory.

Every one of the underwriters' rules represents thought, investigation and experience.

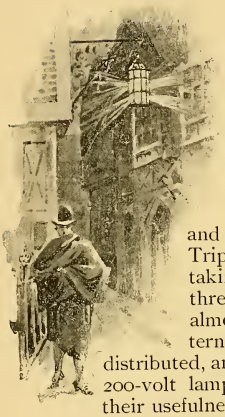
The base rate of the rate of insurance for central stations which conform in all respects to the requirements of the underwriters is 50 cents per $100. For every point in which a station fails to conform to the requirements, a certain addition is made to the rate.

The underwriters recognise thirty-four specific causes for raising the rate above the base or minimum amount. These causes are violations of the rules and regulations, and do not consider "external fire protection," "other occupancy," "condition," or "exposure." A specific addition is made to the rate for inadequate fire protection, and an addition is made for other occupancy, condition, exposure, according to hazard. The thirty-four causes just mentioned are all violations of the regulations concerning construction of building, electrical arrangements, or care and attendance, and are, therefore, all causes within the control of the owner.

These thirty-four causes may, if they all exist, raise the rate to over $10 per $100, but of this sum, over $5, or more than half the amount, is due to the following causes:—Improper arrangement of stack, defective wiring, improper construction of switch board, improper construction and placing of rheostats, storage of oils, gasolene, etc., in station and improper storage of ashes. All of these are defects that should and always can be avoided, and usually at small expense.

ELECTRIC HIGH-PRESSURE CONCENTRIC CABLES AND THEIR ACCESSORIES.

By J. Hetherington.

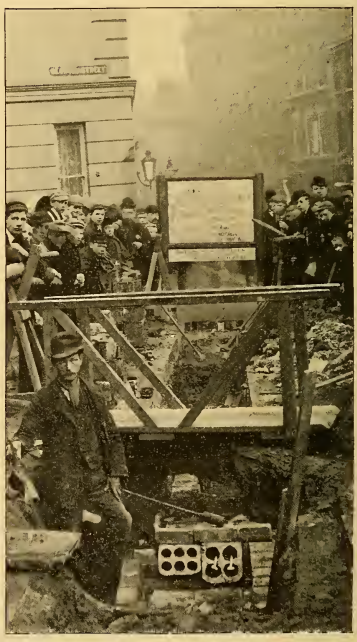


THERE appears to be an unmistakable trend in English practice in the direction of high pressure in the distribution of electricity for public uses, and in the employment of concentric cables, lead-covered and generally armoured. Triple concentric cables are taking a prominent place in three-wire systems, being almost a necessity where alternating current is thus distributed, and the general use of the 200-volt lamp will greatly increase their usefulness.

A concentric armoured cable seems a heaven-sent means to the engineer to get in his copper in streets already thickly crowded with buried, yet living, mains of various kinds where bare copper in culverts, or three separate cables in stoneware conduits, or pipes, would present grave difficulties and greatly swell the cost. Vulcanised rubber as a dielectric is being pushed aside by the cheaper compounds of oil and fibre now used for insulation, both for single and concentric cables, and a high degree of perfection has been attained in their manufacture. The durability of the compounds has yet to be proved while that of rubber is established, but so far its more youthful rivals are full of promise in this direction.

In the extensions of existing low-tension direct-current plants there has been, of late, a marked tendency to lay down high-tension alternating additions to supply outlying districts with banked transformers in sub-stations and low-tension distribution therefrom. But as there is ever a striving after simplicity in engineering practice, it would seem likely, in time to come, that lighting schemes, planned *de novo*, will obviate this composite arrangement by being altogether alternating from the commencement.

Alternating systems are just as convenient as continuous systems for near



CABLE SUBWAYS AT NOTTINGHAM.

distribution, while they are the only systems that have made headway for distant supply. Arc lighting can be carried out by rectified currents from them, if alternating current arcs are objected to, and motors require little consideration in England as yet. Then, also, the alternating system gives the engineer advantages in the flexibility of his equipment to which the continuous system can make no claim.

It fell to the writer's lot to have the supervision of the first concentric cables laid in London, and in 1890-1 he laid nearly 50 miles of three different makes of cable. Of one, insulated with jute and rosin oil, there were 17 miles, all lead covered and laid directly in the soil with no protection other than the ribbon armour wound upon it. There has not been a single electrical failure in this lot up to the time of writing, although working at a pressure of 2400 volts and with hundreds of service lines tapped from it.

Another make, to the extent of 10 miles, lead covered only, was drawn into cast iron pipes, and jointed with plumbers' wiped joints. Two of these joints have failed and that is the record after five years under 2400 volts. The cable is insulated with cotton and rosin oil, and has hundreds of services tapped on to it. The third cable is built up of copper tubes, insulated with paper, soaked in paraffine wax, and enclosed in an outer iron tube, laid in a trough, filled with pitch.

Here there are nearly 25 miles of cable with joints at every 20 feet, working at a pressure of 10,000 volts. What has been its record? If we put aside the failures at the joints, it is nearly as successful as the others. There may have been in the whole 6000 lengths a dozen bad ones, the defect invariably being that the insulation was not put on tightly enough, so that when the outer copper tube was drawn through the die, the loose paper on the inner creased and crumpled. If this cable could have been enclosed in a lead tube, so that impervious joints could have been assured, it would have been practically a perfect cable for the work. As to the 17 and 10-mile lots above, they would have given equally satisfactory results if laid in a river, and, it may be added, that no cable or culvert is reliable for underground work that will not answer this requirement.

A good deal used to be made of the inability of the armour to protect the cable from injury by picks and shovels. From a very wide experience the conclusion has been forced on a mind somewhat biased in favour of stronger protection, that armour, made of two steel ribbons, served on the cable with a cushion of tarred jute between it and the lead, is quite as safe as more costly pipes and conduits, though, of course, at a disadvantage as regards drawing out.

There can hardly be any soil on the crust of the earth so diligently delved in and broken up as that underlying London pavements. Wedges and sledges, picks and shovels are unceasingly plied by navvies, second to none in strength, and the will to use it; yet, of the above 17 miles of armoured cable, nearly 3 inches in diameter, interred in this restless mould, only one fault has been caused by a pick; two others by wedges, and a fourth, where the armoured cable was drawn into a 3-inch cast iron pipe, by a wedge driven through pipe and cable both. In all four, the accidents occurred on the live cables, and in no instance were the men aware that any injury had been done.

Nor have the 25 miles of paper-insulated cable in wrought iron tubes had less immunity. These cables are about 2¾ inches external diameter and have only twice been short-circuited by wedges. On both occasions the wedges were driven through the cables while under a pressure of 10,000 volts with 700 horse-power behind it, and both times the workmen were in complete ignorance of any damage being done,—a pretty conclusive proof of the safety of the concentric system.

Fig. 1 shows at once the operation of the wedge and the method of laying these cables. The wedge has gone through two inches of mastic asphalt in addition to the iron and copper tubes

forming the cable, so that nothing less than armour plating can be depended upon to turn aside a navvy's wedge. In Paris concentric cables are laid with extraordinary precautions. A foot thickness of sand is laid in the trench as a bed for the cables, terra cotta tiles

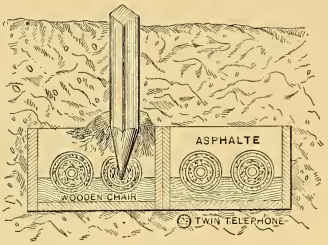


FIG. 1. SHORT CIRCUITING A CABLE.

are laid over them, in addition to their ribbon armour, and over the tiles wire netting is laid in the soil to entangle the tools of the wayward excavator.

Perhaps French navvies are more delicate in their ways than the British variety. The latter would exhume and carry off the wire netting to confine his fowls, and the tiles to roof their pen, while the builder would snap up the sand as a treasure of great price. At Cologne, in Germany, also, the armour is distributed and the concentric cables in use there at 3000 volts are not only armoured, but laid in troughs filled with asphalt as in Fig. 1. The asphalt on the 10,000-volt cables has to serve the treble purpose of giving mechanical protection; preserving the outer iron tubes; and making the joints in the latter impervious to moisture.

Another class of armour consists of galvanised iron wires, say, of No. 12 gauge, laid spirally on the cable. This is used on services and small cables, but, obviously, is no protection at all against a sharp point. On the contrary, the wires tend rather to keep the point on the cable than to divert it.

The concentric armoured main is absolutely safe against gas explosion, whereas whenever culverts or pipes are used, there is risk in such a gas-sodden soil as that of London. Even the telegraph wire boxes blow up, and a large culvert may easily become a veritable mine in the middle of a thoroughfare. What scope for the penny-a-liner the blowing up of a culvert of two feet cross-sectional area in Piccadilly would afford! With a heavy omnibus traffic, several of these top-heavy vehicles might suddenly be let down on one side to a depth of three feet, and for a good many passengers the question as to whether the gas or electric company was liable would possess small interest, however it might affect their heirs and asigns.

Happily the danger is becoming more remote, thanks to careful ventilation, and the culverts of concrete, stoneware and cast iron may endure for many years. This is more than can be said of unprotected wrought iron pipes of which enormous quantities have been laid in London, for in the lifetime of many, now past the climacteric, most of these will have become hydrated

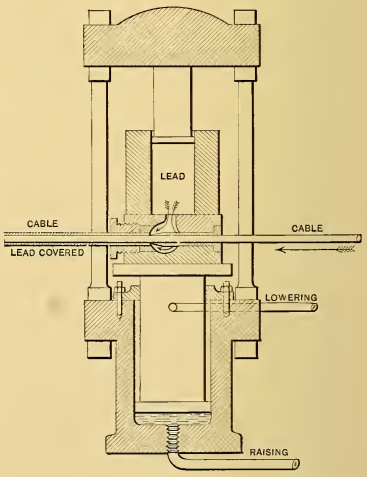


FIG. 2. PUTTING LEAD ON A CABLE.

peroxide. The ribbon armour used on cables is, of course, equally perishable, and it is of the utmost importance to serve this on the cable not only with

a thorough coating of coal tar, but also to cover it with jute soaked in this material or something equivalent. For want of the preservative the writer has taken up armour, after six months in the soil, as rusty as old hoop iron on a garden fence.

On all compound cables water tight-

FIG. 3. CONTINENTAL PRACTICE. FIG. 4. ENGLISH PRACTICE.
LEAD COVERING.

ness of the lead case is of the first importance. A fault is only a matter of time wherever there is a fissure, and to guard against this escaping notice, the cables should have a twenty-four hours' immersion in water, the insulation resistance being measured before and after. The lead itself seems durable in London soil; the writer has never seen the smallest sign of corrosion in a lead-cased cable.

In English cable practice the lead is put on heated, but not molten, by ram for the water and a small one for the lead. The latter is a fixture, the cylinder which contains the lead being forced upwards. By this process a reliable covering can be put on at one operation, differing in this respect from continental practice, where the lead is put on molten, at a pressure of about 900 pounds per square inch, and three coats being served.

Cables made by each method may be compared in Figs. 3 and 4 where it will be seen that a covering of lead is put on the inner insulation before the outer wires are laid on the core, and that two coats of lead are put over the outer insulation. This implies that the cable must be twice treated with the insulating compound as well as going three times through the lead process. In the Paris cables the outside diameter is about 4 inches; the pressure used is 3000 volts.

It has again and again been preached to the electrical profession by cable makers that high insulation resistance means neither durability nor resistance to disruptive discharge. It is repeated here once more, because in some recent specifications enormous megohms per mile are set out and these can only be attained in a compound cable by processes which manufacturers' experiments have proved detrimental to the durabil-

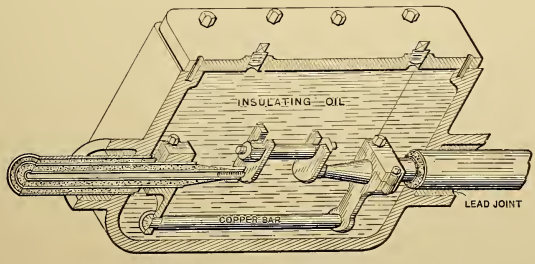


FIG. 5. DISCONNECTING BOX FOR A 10,000-VOLT CABLE.

means of a modified hydraulic lead press of the kind shown in Fig. 2. This process requires a pressure of fifteen to twenty tons per square inch on the lead, obtained, as will be seen, by a large ity of the dielectric without adding to its efficiency as a non-conductor, and it is repeated also because, as a cable user, experience with both high and low-resistance compound cables has taught

JOINING CABLE ENDS.

the writer the fallacy of high megohms. The 10,000-volt mains from Deptford registered less than 800 megohms per mile when new, but they work well enough notwithstanding; while certain other cables which gave insulation resistances, at the start, of 6000 megohms, have frequently been pierced by a pressure of 2400 volts after a few years, and sometimes after a few months, or even days, of work.

Cable makers have necessarily made exhaustive trials of all kinds with the particular dielectric they affect, and so long as they guarantee the successful working of the cable at the specified pressure, it is best to leave the details of manufacture to them. Cable making is more complicated and as yet less generally understood than the making of concrete.

Lead-covered cables are often jointed in cast iron joint boxes, clamped to the lead and filled with insulating oil. There is a tendency for the oil to escape into the cable between the lead and the insulation, to occupy the space made by the stretching of the lead on the outer side of the coils on the drums. On hilly ground the boxes may, in this way, be drained nearly empty, and, as water is ever on the watch to enter any vacant space inside the cable's system, it is a wise precaution to have oil boxes examined at intervals of a month or two and the oil renewed where necessary.

The water, when it does enter, forms pits in the surface of the oil when the latter is heavy enough to support it, and in this way the great depth of oil on top of the fittings has several times saved the earthing of the inner pole in the box shown in Fig. 5. These boxes

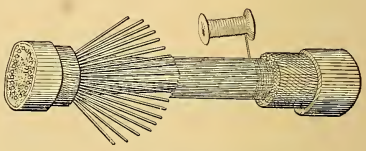
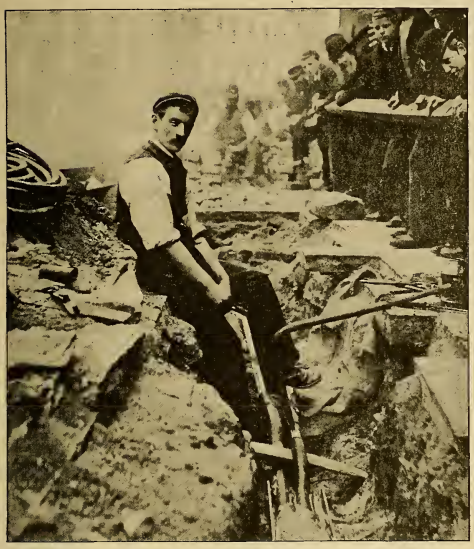


FIG. 6. COPPER SLEEVE AND BINDING WIRE.

are provided with covers, fitted better than those on many a steam engine cylinder. They stand quite free on all sides, in brick pits in which there is no visible trace of water, and yet have been found to contain quite alarming

amounts of water on top of the oil. The "cussedness of things inanimate" is, however, a characteristic with which most engineers are familiar, and this particular phase is best combated by an occasional unscrewing of the plugs



MAKING A JOINT IN A STREET TRENCH.

to ascertain the condition of things inside the box, and by the use of an oil of high specific gravity on which water will float. For the above reasons semi-solids are better for charging joint boxes in all cases where the box is not likely to be opened after being once filled.

In the general aspect of the joint boxes now in use, there has been little change in the past ten years, practice in this respect having settled down into a stable condition. The boxes almost invariably divide at the centre line of the cable, with a groove in the lower half, to receive a corresponding tongue in the upper. Between tongue and groove a piece of ¼-inch lead is fixed, and the ends around the cable are made good by some semi-solid compound, run in hot. By dividing at the cable, the jointer has plenty of room to make his joint, as he can put the iron cover on after the connections are all complete.

The box shown in Fig. 5 is very awkward in this respect. The fittings used inside the boxes regulate the size, and in London it is necessary to reduce the dimensions to the smallest limit that safety will allow, because of the cramped spaces usually found in the streets. Of course, economy in insulating material points in the same direction, but there are boxes in use to which neither consideration seems to have been applied, boxes that (regard being had to their purpose) are simply colossal. The most compact concentric joint is made by scarfing the inner wires, as usual with a single cable, then insulating by tapes and making the outer wires continuous again through a tinned copper sleeve to which they are firmly bound down and soldered (Fig. 6). The underside of this cannot well be soldered, but some jointers put on plumbers' metal, as in making a wiped joint. The outer wires are again wrapped with tape, and a close-fitting cast iron box, bolted on and charged up with compound, completes the joint.

The latter is of use only for perma-

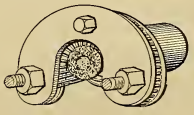


FIG. 7. FLAT TEE-JOINT CLAMPS.

FIG. 8. SPLIT TEE-JOINT CLAMPS.

nent work since it cannot be got apart without ruining the outer wires. Sometimes a lead sleeve takes the place of the iron box, with plumbers' wiped joints

to make watertight connections to the lead. Some dielectrics will not stand the heat engendered in the cable by the bulbs of metal, and the writer has seen

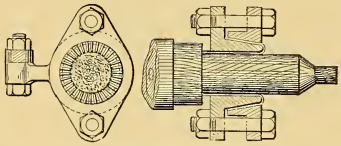


FIG. 9. CONICAL CLAMPS.

several faults where a hole was melted right through the bulb. Of course, for armoured cables the iron box is indispensable, unless a brick pit be built around the lead-covered joint.

The commonest type of mechanical connection for the conductors is a tube, split or solid, for the inner ones, run in with solder, and for the outer ones, two flat clamps between which the wires are turned up and gripped by bolts, the current being passed through two of the bolts to the corresponding clamps on the other side of the joint. These clamps encircle the cable where the inner is divided (as at a straight joint) and the wires are evenly laid in all round. For a tee joint, the inner is not divided, however, and hence the clamps are made in the form of a horse shoe, as shown in Fig. 7, so as to drop over the cable—a form which makes the lower wires rather difficult to manage.

This difficulty has been got over by splitting the clamps with joints at right angles, as in Fig. 8, lugs being provided to connect from clamp to clamp. These first clamps more or less hang on the wires and are easily racked about, so that some makers put a ring of ebonite around them to prevent accidental contact with the ironwork; while, unless they are made of great substance and with large bolts, they cannot be made to

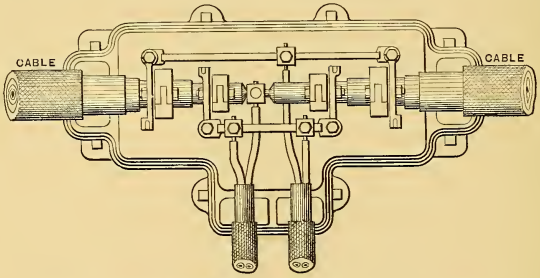


FIG. 10. TRIPLE CONCENTRIC CONNECTION FOR TWO HOUSES.

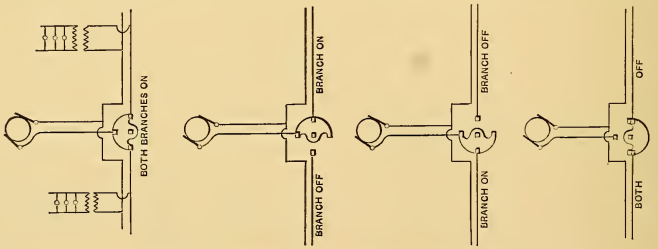


FIG. 11. THREE-WAY ROTATING STREET SWITCH.

bite on all the wires in a satisfactory manner, particularly if some are a little "proud" or full in diameter.

This has led to the introduction of a patented fitting, shown in Fig. 9, which is bored so as to slip over the wires and these, being turned back over a cone, are jammed by a conical ring so as to be

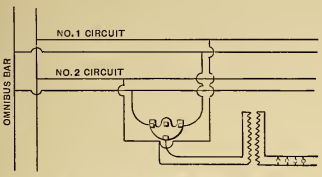


FIG. 12. TWO PARALLEL MAINS WITH 3-WAY SWITCH.

wedged down on the fitting. The soft copper of the wires is flattened where there is any irregularity in size and the fitting has a solid bearing on the core of cable. By keeping the angle of the cone low, the ring will wedge itself so firmly on that permanent bolts are not necessary, a temporary clamp being used to force it down. Both parts are hinged for tee jointing, and for low-tension triple concentric cable work the

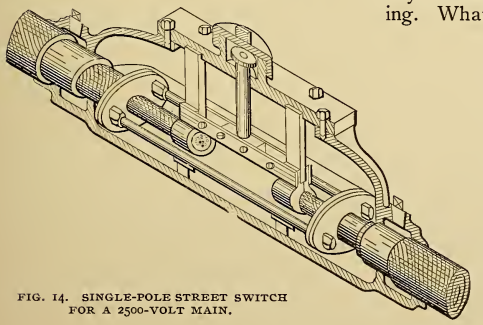


FIG. 14. SINGLE-POLE STREET SWITCH FOR A 2500-VOLT MAIN.

male cones are put on and bolted up before cutting the conductors to which they are to be applied, so that the supply of current goes on through the fitting while the joint is being made.

Fig. 10 shows the arrangement of a triple concentric house-box with these fittings, whereby two consumers are put on at one joint. A plug is provided to block one outlet if only one is to be connected, and this can be removed and a second put on at any time. In securing wires by all the above fittings, the bearing is more or less only on a line along the opposite sides of each wire and where large wires are used this may

FIG. 13. RING MAIN WITH 3-WAY SWITCH.

represent a less sectional area than that of the conductor. For such cases the male cones of the above fitting can be lined with solder or fitted with grooves into which the wires are bedded by the ring.

It is, of course, impossible to do anything on high-tension cables while the current is on, and in order to minimise the inconvenience to consumers, jointing, in and other operations, are generally done in the small hours of the morning. Whatever the hour, there is pretty certain to be some consumer on the circuit looking for a burglar or entertaining a birthday party when the current is cut off, and in the fierce competition prevailing in London between high and low-tension companies, the complaints of consumers receive very respectful attention. High-tension systems with transformers in all the houses supplied, are always arranged in a number of circuits, but a whole circuit is often too large a unit to be altogether disconnected, since some are nearly three miles in length.

By means of a ring system, the conductors being taken into and out of every house, any part can be disconnected by taking the cables out of the

fuse blocks at the extremities of the part. Thus, on a ring along the Strand and supplying Nos. 12 and 20, say, it is desired to connect No. 16. The ring is fed at both ends, and by removing the ends of the piece between 12 and 20 from the fuse blocks in the converter chambers, the cable is made dead between these points, the supply to them meanwhile being uninterrupted. The cable between is then cut and carried into No. 16 and similarly connected again, a new piece being put in all the way from 12 to 16, instead of jointing outside, the drawn-out piece going to store, to be used where it will come in for another similar service. This is the plan in use with non-concentric cables at 1000 volts by the Metropolitan Corporation, in London, but the writer is unaware whether the ends are taken out of, and put into, the fuse blocks while they are alive.

The breaking of a circuit with a concentric cable is a simpler matter, particularly if the outer member is at the earth's potential, as only one pole needs to be broken. By means, for instance, of a patented rotating arrangement, on the principle of a three-way cock, either or both branches can be disconnected or supplied from a main at will, as in Fig. 11, which shows the four positions of the switch. There is no blink, even, of the lights in the parts of the circuit not required to be disconnected.

Another use of this switch is shown in Fig. 12, where two parallel mains are passing an important installation, or a transformer sub-station. The supply can be from both mains (as shown in the figure) or from either circuit, or cut off both. Again, in Fig. 13, a ring main, passing a similar installation, can have either half disconnected while the supply can go on through the other half. Other uses will suggest themselves.

These switches are in use on 2000-volt circuits and break under heavy oil. They are worked by a box key from the street, exactly as a cock would be, a dial outside the case indicating the position of the switch within. The extreme sizes of this switch-box are about 24 inches long by 16 inches wide and 8 inches high.

For long straight mains, a switch is used by the London Corporation as shown in Fig. 14, where a cross plug is lifted by means of an ebonite handle, the handle being then screwed off and a ring screwed on in its place to prevent the plug dropping. Two ebonite guides obviate any lateral displacement of the cross plug; it can go only on to its

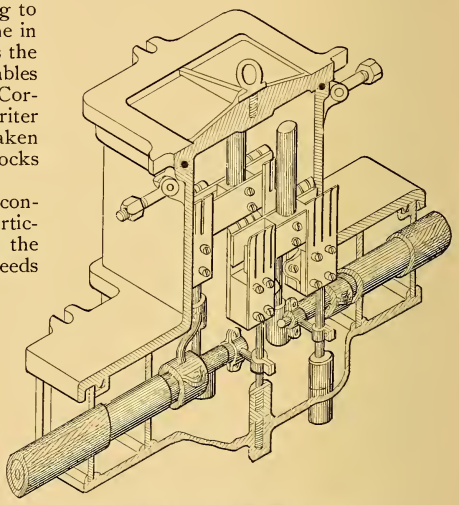


FIG. 15. FRENCH DOUBLE-POLE STREET SWITCH.

place. As the inner wires to which the contacts are soldered would yield under the pressure in putting on the plug, two ebonite supports are put underneath and pinned into position, while the ebonite guide pieces hinder any lift when the switch is pulled off.

The box is in two halves and bolts on around the main in the same way as joint boxes do; its outside sizes are 26 inches by 10½ inches in plan and 11 inches in height. The break has been exaggerated in the sketch to make the action clear; it is 4 inches from terminal to terminal. The outer wires are con-

nected through ordinary flat clamps with long bolts, as in mechanically made straight joints. This switch works perfectly under heavy oil, with by any fault as well as partially locating it, and on this account is worth attention.

Another arrangement, worked by

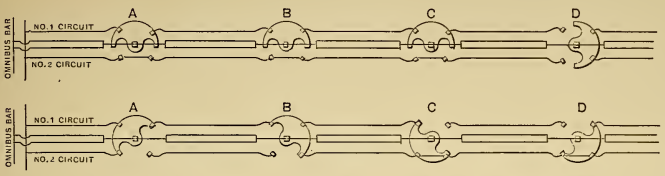


FIG. 16. FOUR-WAY ROTATING STREET SWITCH FOR TWO PARALLEL MAINS.

2400 volts on the main, and has carried as much as 200 ampères.

It presents a striking contrast to that shown in Fig. 15, used in Parisian streets, in the Secteur des Champs Elysées on a similar concentric cable. In this case both poles are broken by cross plugs with ebonite and wood insulated handles, rubber gloves being also worn by the operator. Ebonite insulators are screwed into the bottom of the box to carry the upright rods on which the contacts are clamped. A semi-solid compound is poured into the box to the level of the contacts and the latter are in air, which is deprived of its moisture by trays of chloride of lime enclosed in the upper compartment. The outside sizes of this box are approximately 30 inches by 21 inches in plan, and 27 inches in height. The pressure is 3000 volts and the break between contacts is three inches. In the Cologne scheme there is a complicated ring system of concentric mains split up into sections by mercury switches.

So far as the writer can find, there are no high-tension mains fused in sections outside the station in England, but the plan here shown has the advantage of reducing the amount of circuit affected

the patented rotating switch may be seen in Fig. 16, where two parallel concentric mains are brought into one box, and by rotating the switch any section into which the circuits are divided by

POURING A JOINT.

the boxes may be disconnected without even a momentary interference with the supply to the other parts of the system. As shown in the upper diagram, the mains are in two separate circuits as far as the box *D*, and are both made dead beyond this point by turning the switch as shown and then removing the

cross bar of the lower pair of contacts. In the lower diagram the section *A* to *B* on No. 2 circuit is disconnected, the discs being first put into the positions shown, and the cross bars afterwards removed, and the section *C* to *D* on No. 1 circuit is disconnected by moving these discs as in the diagram, the cross bars in this case not being disturbed. The outer pole is made common

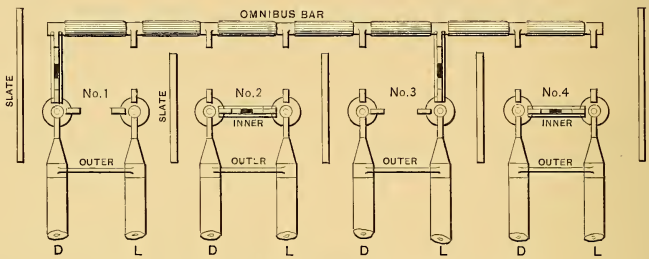


FIG. 17. CROSS CONNECTION GEAR FOR 10,000-VOLT MAINS.

through the boxes and is not interfered with by the switch. The mains, of course, may make any detour that may be desired through adjacent streets. The switch works up to 3000 volts. The overall dimensions of the box in this case are 30 inches by 16 inches in plan, and 13 inches in height.

This switch may make it worth while to lay two mains side by side, of smaller section, instead of one of large section, —an arrangement which has advantages where great current density has to be

they would offer greater surface on their cores for the guidance of the current, while connections could be made between the boxes without discontinuing the general supply.

The London Electric Supply Corporation have four trunk mains in parallel between Deptford and London, a distance of about six miles, carrying current at 10,000 volts. No switch of the above character could be safely worked at this pressure. The switches at the generating station have moving connectors, six feet long, giving four feet break when pulled off. But it is occasionally necessary to work on parts of the mains, while it is of the greatest moment to have as many of the four mains available as possible.

With this end in view, cross connection stations are provided along the route of the mains into which all four are taken and brought out again, as

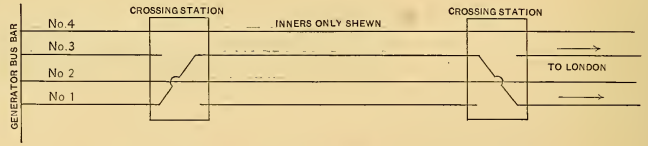


FIG. 18. CROSS-OVER CONNECTIONS ON 10,000-VOLT MAINS.

used with alternating current. Assume, for example, that a concentric main of 0.25 square inch sectional area in each conductor was to be laid; then two mains of half that area would cost more in about the proportion of 12 to 9, but

shown in Fig. 17. The mains from Deptford are there marked *D*, those going on to London, *L*. The inner of these are connected to insulated blocks fixed to the wall and usually connected across by plugs, as shown on Nos. 2

and 4. An omnibus bar is fixed above with contacts corresponding to each of the eight blocks below.

If now, it were desired to have No. 3 main disconnected between Deptford and the first crossing station and No. 1 main between the two crossing stations, as shown in Fig. 18, the plugs connecting the inners of $1D$ to $1L$ and $3D$ to $3L$ would be taken off, the mains being dead, and $1D$ would be carried up by a plug to the omnibus bar, and current taken through the bar down by a plug to $3L$, as drawn in Fig. 17. The outers remain permanently connected both in the crossing and generating station, and at the latter point they are all made common to one earth.

The cost of concentric cables is about 7 to 8 per cent. greater than two single cables of equal sectional area, both being lead covered. The armouring generally used is much cheaper than the cast iron pipes, being about one-fourth to one-sixth of their cost (the difference diminishing with the size of the cable), and it is doubtful if the ability to draw in and out is worth the cost of the pipe. In the writer's opinion the cost of pipes can be more economically sunk in copper at the outset, a 3-inch pipe representing, in this respect, about 0.1 and a 4-inch pipe about 0.15 square inch sectional area of two conductors.

Where armoured cables are used, it is very necessary to get in the outside section at the beginning as the cost of laying mains is enormous in London, and often varies greatly in the different districts and parishes into which London is divided; the writer had sixteen different scales of charges to deal with in as many parishes.

In this instance the dearest parish for reinstatement cost, per yard run, five times as much as the cheapest, and three times the average of the sixteen for similar work, the difference being almost entirely due to the different methods of the surveyors. Where the reinstating is allowed to be done by contractors, it can be done at a fair profit for less than half the average vestry charges and to the vestry's satisfaction, so that, although municipal labour is a very fine thing, it is not coincident with economy where a company without voice or control in its direction has to settle the bill.

In concluding, the writer may express his belief that the Deptford scheme has demonstrated that current can be generated at high pressure (some of the dynamos can work at 13,000 volts) and directly transmitted from the machines by underground concentric cables with safety and certainty to distant transforming stations, where it can be lowered in pressure to anything that may be necessary. Transformers are now at work reducing from 10,000 to 100 volts at one step.

Current Topics.

Ice machine builders might well turn their attention to the making of small outfits, one-ton machines, say, rather than those of fifty or a hundred tons, and reasonably expect to find the business profitable. There are many relatively small consumers of ice who would gladly avail themselves of the advantages which a small plant would offer and who, in the aggregate, would probably amount to considerably more in a business way than the few-and-far-between establishments that need, and can afford to pay for, a machine of ponderous size and capacity. And yet, few ice machine companies have apparently given this aspect of the matter any particular consideration. With the necessarily restricted demand for large machines, and the evident inclination of the makers to turn out no others, it has become necessary for them to cast about for other kinds of business to help them keep their shops in work, and thus it is that we find many of them engaged in various side lines of manufacture, turning out things originally quite foreign to their intentions and equipment. If there be money enough in this to make it pay, there is little to be said against it, though it does seem unfortunate that an establishment should reach out into other lines and neglect its own specialty for which there is a growing and unsatisfied demand. Small ice machines are clearly destined to become more and more important accessories to modern conveniences and the firm that will be first prepared to offer them will reap a good business reward.

The purest water often is the most active in corroding and pitting boilers,—a fact which seems quite contrary to what one should expect, but which, nevertheless, is one of common observation. The active corroding agent, in some cases at least, is probably the oxygen of the air, of which the water is capable of dissolving a considerable amount. The corrosive power of such pure water on new or unscaled boilers was well illustrated in the city of Glasgow when a new water supply was introduced from Loch Katrine, one of the purest waters in the world available for city consumption. The facts, taken from *The Locomotive*, are credited to Rowan's little hand-book on "Boiler Incrustation and Corrosion." The former supply of Glasgow had been poor and calcareous, and old boilers were

much coated with lime scale. To the dismay of the users, those who had put in new boilers, or new tubes, found them rapidly corroding, while the old scaled and coated boilers remained as before, and those who had removed every possible trace of old incrustation from their old boilers, by mechanical or chemical means, "in order to get the full benefit of the pure water," were also badly troubled by corrosion ; and even the old boilers, as the scale was gradually removed by the unvaryingly soft, pure water from the lake, were more or less corroded when no means were taken to prevent it. It was found, in this case, that introducing a little lime from time to time,—enough to give the boilers a slight calcareous coating,—usually prevented the corrosive action of the water, and in the course of time the lime, organic matter, and iron oxide skin formed a protecting, oxidised surface that prevented further corrosion.

To the above *The Locomotive* adds that water similar to that of Loch Katrine,—soft and pure in quality, without alkalinity, containing some vegetable organic matter, and with the natural proportion of acid and gases common to a fully oxidised water,—is what in the non-lime bearing sections is met with at certain seasons of the year in streams, ponds, and reservoirs, after the melting of snow or heavy rains. Except in certain limited sections, however, this condition fortunately does not long persist, for in dryer times the water soon takes up its normal proportions of lime and alkali, and reaches the point where some scale may form in a boiler. It will be inferred, from what has been said, that the most perfect boiler water is one which makes a slight deposit in the dryer seasons, and has this deposit largely dissolved off by the soft water of spring and fall, so that the balance of efficient working, without much scale and without serious corrosion, is practically kept. Some boiler waters fulfill these conditions. It will not do, however, to rely entirely upon nature to keep the balance in even the best boiler waters, for the condition of the water will vary from season to season, and even the smallest amount of solid matter, whether soluble or not, will accumulate, in time, to a dangerous extent if not blown out or cleaned out.

READING, the other day, of fusible plugs for boilers, called to mind an incident which is said to have happened several years ago in a place where an old-fashioned haystack type of boiler was in use. On one occasion a rivet was blown out at a point difficult to get at for repairing, and as a makeshift the engineer put in a pine plug, driving it into the hole from the inside. It is not remembered how long this plug lasted, but, at any rate, it tided over an emergency. The plug, it was found later, burned off until the leakage through it was just sufficient to prevent further charring, and while it was in operation, no doubt, performed the part of a safety plug, for, had it become uncovered, it would, in all probability, have given way with quite as much celerity as the ordinary fusible plug.

THERE is a growing tendency among the miners and exploiters of mines in the western part of the United States to utilise as motive power, streams which not so very long ago would have been considered unworthy of consideration as sources of power. Men are beginning to learn that head counts as well as volume and that a tiny stream with several hundred feet head may be as valuable a source of power as the more imposing fall of much lower head. Then, too, the little stream needs no expensive dam or head works to confine it, but can be trapped and guided at comparatively small expense, and instead of being allowed to fall freely, it can be led into a pipe which impounds it all, and thus it can be confined and led perhaps five hundred to a thousand feet down the mountain, accumulating pressure as it descends until it shoots

out with full force against the buckets of the Pelton wheel, or quietly exerts its statical pressure in the chambers of a direct air compressor.

Not so very long ago the writer saw a plant being installed over eight thousand feet up in the Rocky Mountains, and the primitive pipe-making establishment was very interesting. Rather than incur the expense of hauling the wrought pipe, a small pair of bending rolls had been procured and these, with a portable forge, constituted the equipment. Under a frame shed by the mountain side, three men were turning out length after length of riveted sheet-iron pipe, right at the place where it was to be used, and the pipe-line was being constructed five hundred feet up the cañon, bringing down over two hundred horsepower to the spot where it was to be utilised. The operations seemed somewhat primitive at first sight, but the expense account of the establishment was a minimum, and when the cost of burro train and the railway freight, and the profits of several middlemen were taken into account, the miners were probably ahead in the long run.

An amusing instance of anticipation of the penetrating character of the so-called X rays, has been discovered in a most unlikely place—*i. e.*, in Dickens' *Christmas Carol.* It will be remembered that when the miser Scrooge sees the ghost of his former partner Marley entering the room, Marley's body appears to be transparent, so that Scrooge can see clear through him and discern the two buttons on the back of his coat. It may be presumed that Marley wore the old-time blue coat with brass buttons, and that flesh and blood became transparent when metal buttons would not. It is now in order for the Society of Psychical Research to try the X rays for the detection of ghosts, but if they are successful they must give the credit to Dickens.

Some time ago a queer story came from one of the English coal mining districts where some of the mines had been drowned for years, and the many attempts to pump them dry had been ineffectual. After many thousand pounds had been spent in pumping, without doing any good, it was found that the water raised by the pumps had been allowed to find its way back into the mines though old shafts, crevices and other avenues. It made both amusing and instructive reading, but if one simply changed the names, the whole account sounded not much different from one hundred and one things within the experience of undoubtedly a great many engineers. Work is performed over and over again to no purpose, just because care is not taken to see that every stroke tells.

One of the most interesting places for the engineer to visit at Washington, D. C., is the headquarters of the Inter-Continental Railroad Survey. The great work of preparing the preliminary plans for a railway to unite North and South America has been going on in a quiet way for several years. The survey has been carried southward by Mexico and northward by Brazil, while the detailed connecting survey has been done in Central America by a detail of United States Army officers under the very efficient direction of Lieutenant Macomb. The results of the field work are now being reduced and computed and the topographical maps which have been prepared will compare most favourably with the finest work in any country. The extent of the survey involved geodetic work of magnitude, and the final results checked up in a most satisfactory manner. Many of the altitudes were first determined by the barometer, and the chosen altitudes were subsequently measured either trigonometrically or by spirit levelling, and the closeness which appeared between the barometric determinations and the subsequent measurements was most gratifying to those who believe that the ba-

rometric method still has a great future before it. When this great work is presented to the engineering profession in its entirety we believe that the portion of it which has been performed by Lieutenant Macomb and his associates will be recognised as a remarkably beautiful and accurate piece of geodetic work, performed in the face of many and great natural obstacles.

Of the engineering instinct, if it may be so termed, of some of the lower animals, an admirable example is given by Dr. James Weir, Jr., in a paper recently published in the *Medical Record*. "Several years ago," he says, "I noticed that one of the combs in a beehive, owing to the extreme heat, had become melted at the top and was in great danger of falling to the floor. The bees had noticed this impending calamity long before I had, and had already set about averting it. They rapidly threw out a buttress or supporting pillar from the comb next to the one in danger, and joined it firmly to it, thus shoring it up and preventing its fall in a most effectual manner. When they had made everything strong and secure, they went to the top of the comb and reattached it to the ceiling of the hive. After this had been done to their satisfaction, they removed the shoring pillar and used the wax elsewhere. In this instance there was an immediate adaptation of themselves to surrounding circumstances, in which they averted and prevented an utterly unforeseen and unheard-of catastrophe by means as effectual as they were intelligent. Could man do more or reason better? Here was an experience which had not happened to them in hundreds and hundreds of generations perhaps, which perhaps had never happened to them before, and yet when it did happen, their quick intelligence readily grasped the situation and they at once set about remedying the evil."

The proper arrangement and management of tool rooms in machine shops was recently made the subject of a committee inquiry on behalf of the Central Railway club and at a meeting of that organisation, a short time ago, the recommendations of the committee were presented in the shape of a paper by Mr. S. Higgins. One of them was to the effect that a list of all workmen entitled to obtain tools from the tool-room should be printed alphabetically, and each name should be numbered in consecutive order. The list should be neatly framed and hung up in the tool-room near the delivery window. Each workman whose name appears on the list should be furnished with six brass checks, each check bearing the number that is opposite his name on the printed list. At the outer end of the pocket provided for each tool, there should be a wire brad or nail, so that when a tool is taken out, a brass check, bearing the number of the man who has the tool, can be hung up on the brad, which will indicate what workman has that particular tool, and it should be the invariable rule to have all tools returned to the tool-room at the end of each week, so that they can be examined by the man in charge, and prepared for delivery at the commencement of the next week, as may be required.

The delivery of the tools to the workmen was to be accomplished in the following manner:—An electric annunciator should be set up in the tool-room in some convenient location, with buttons located at different points in the shop where they will be the most convenient to the men in the different departments. There should be a small blackboard at each button, divided off by five or six horizontal lines, with a brad or wire nail at the left hand side of each space made by the lines mentioned. When a workman wants a tool he should push the button, then write in one of the spaces in the blackboard the name of the tool required, and hang his tool check on the nail opposite that space. There should be two or three boys in the tool-room, one of whom should go to the

station rung up on the annunciator, remove the tool check, see what tool is required, bring the check to the tool-room, hang it up in place of the tool, then take the tool to the blackboard where the workman can get it. In order to prevent delay, and to carry out this scheme successfully, the workmen should not wait until they actually want a tool, but should anticipate their wants, so that the tool can be brought to them by the time it is required. The returning of the tools to the tool-room can be handled in the same way as the delivery of the tools to the workmen, provided the boys who distribute the tools know where each tool belongs when it is returned. With this arrangement, boys, paid relatively low wages, can attend to the distribution of the tools, rather than have the workmen do it, who receive a much higher rate of pay.

In commenting on the skill shown by the late General Casey, chief of engineers of the United States Army, in estimating in advance the cost of various engineering works, the *Army and Navy Journal* recalls some of the errors made by others in similar calculations. Thus, the estimated cost of the Manchester ship canal is stated to have been £5,750,000, but nearly £16,000,000 were spent before the canal was ready for business. The international commission reported in 1856 that the cost of digging the Suez canal would certainly not exceed £8,000,000. But it cost £18,900,000, to say nothing of Egypt's gratuitous building of lighthouses, dredging of the harbours, advance of money without interest, and gift of forced labour, the whole amounting to £4,000,000 more. Engineers spent a year collecting data for their report on the Congo railroad, which they asserted could be built for £1,000,000. They now say that the total cost will be from £2,400,000 to £2,600,000. The egregrious underestimate of the cost of the Panama canal nearly swamped that enterprise before wholesale stealing completed the ruin. The forts on the Meuse river, estimated at £900,000, cost £3,200,000; the Corinth canal cost £2,400,000 instead of the estimated £1,200,000; a harbor and a railroad on the island of Reunion cost £2,700,000 instead of £1,560,000; the Senegal railroad, which was to be completed for £520,000, absorbed £1,800,000, and the Langson railroad in Tonkin, which was to open a conquered province for an expenditure of £100,000, bled the French treasury to the tune of £873,558.

Paint for machinery was made the subject, a short time ago, of a little sermon by Mr. John Richards, who is well known on both sides of the Atlantic through his engineering work, to some perhaps particularly through his part in the development of rational machine tool designs. Said Mr. Richards:— "One must confess to disgust in seeing well-made machinery covered with glistening paint and varnish, showing every pinhole and dentation of surface in the castings. The chromatic part, too, is execrable, with but few exceptions. Think of cast iron being painted with red ochre and varnished; also, in some cases, with white lead, ground in oil, relieved only by grease stains and landscape work on panels. It has long been conventional with makers of good machinery to paint it with lustreless paint of a colour called steel, and as near to that of cast iron as possible. This causes the castings to look smooth, harmonises with finished parts, and permits accurate photographing. Further, in respect to painting machinery, steel-coloured lustreless paint and 'filling,' which is the same thing in a stiff paste, has by common consent become a sign of good taste and good work. Many years ago Messrs. William Sellers & Co., at Philadelphia, made experiments to determine how their machines could be properly photographed. All reflection had to be avoided. That was obvious, so the machines were lime-washed, with different tints, which succeeded, but was a great

deal of trouble because the wash had to be removed and substituted with paint. Mr. Tulley, a paint maker in Philadelphia, took up the matter, and after a long train of experiments produced a lustreless paint that resisted animal oils, and, with a good pigment, lasted for years without change of shade. It also became as hard as iron, and was applied to castings as soon as cleaned and before working them. The works in Philadelphia adopted this paint for machinery, and it has spread a good deal."

SEVERAL years ago a number of experiments were made to determine the value of Portland cement for anchoring bolts in stone, and the results, reported at the time in the *Polytechnic* of Troy, N. Y., U. S. A., are worth recalling now because of their great interest to engineers in such work as fixing holding-down bolts for engine beds, gasholder framing and the like. It appears that certain gantry-work for an elevated railway had to be constructed upon rock so near the surface as to necessitate anchoring the foundation bolts, and as some more durable and cheaper way of doing this than by the use of sulphur or lead was desired, Portland cement was suggested and tried. No records exhibiting the adhesive strength of cement in pounds per square inch could be discovered; hence it was decided to investigate the matter specially. For this purpose fourteen holes were drilled in a ledge of solid limestone, one-half of them being 1⅜ inches and the others 1⅝ inches in diameter, and all 3½ feet deep. Seven ¾-inch and seven 1-inch bolts were prepared, with thread and nut at one end and jagged at the other for a length of 3 feet 6 inches. There were no heads to these bolts; nor were they swelled. Four of them were anchored with sulphur, four with lead, and six with neat cement, both sizes of the bolts being used equally. All were allowed to stand for a fortnight after setting, when a lever of sufficient power was rigged, and they were pulled.

IN sulphur three bolts out of four developed their full strength of 16,000 lbs. and 31,000 lbs. respectively. One 1-inch bolt failed by drawing out under a strain of 12,000 lbs. In lead also three out of four bolts developed their full strength as above; but one 1-inch bolt drew out under a pull of 13,000 lbs. In the cement five bolts out of six were broken without drawing out. One 1-inch bolt began to yield in the setting at 26,000 lbs.; but it sustained the full load for a few seconds before it broke. While this experiment demonstrated the inferiority of cement both as to strength and ease of application, it did not give the holding strength per square inch of area. To determine this, limestone blocks 12 inches thick were prepared, with holes for bolts drilled clean through them. Holes 1¾ inches in diameter were prepared for 1-inch bolts, and 2¾-inch holes for 2-inch bolts. Some bolts were cemented into these holes plain and smooth, while others had screw-threads cut upon them. The specimens were allowed to stand for thirteen days, and they were then pulled in a standard testing-machine. The smooth 1-inch bolt began to yield at 20,000 lbs., and the threaded one at 21,000 lbs. The 2-inch smooth bolt began to give at 34,000 lbs., and the threaded one, at 32,000 lbs. In these tests the pressure was applied very gradually. When the pump was run at a greater speed to represent a more sudden strain coming upon the bolts—the stones split before the bolts yielded. It was thus ascertained that the English Portland cement used was more reliable, stronger, and easier of application than either lead or sulphur for the purpose; and that its resistance as a setting for holding-down bolts is from 400 to 500 lbs. per square inch of surface in actual contact. Moreover, not much appears to be gained in a long bolt by jagging or threading the embedded shank.

IN discussing, in the *Journal of the Franklin Institute*, what he terms the reversal of invention, E. P. Thompson

chooses as a pertinent illustration the present airbrake system as a recognised reversal of the early type of brake, though a long time passed before the change took place. The idea of the new brake did not come by demand of the mind, but by a combination of circumstances; that is to say, accidentally. Of the two systems of brake, the first operates to stop a train by the positive action of compressed air against the wheels through the medium of the usual brake shoes, and the second by the negative action of compressed air, which normally holds the shoes away from the wheels in opposition to a spring. The advantages of the second way, remarks Mr. Thompson, are apparent as compared concerning their main object—safety,—for by the former the train cannot be stopped in the case of a leak or a disordered pump, while with the latter the train stands still as soon as the air leaks out or the pumps refuse to work.

ACCORDING to the *Electrical World* one of the cheapest ground returns that can be built for electric roads, may be constructed of old rails. Flat rails are the most convenient for the purpose and are usually the most available. They may be readily laid between the rails. It is necessary, however, in order that the rail thus laid shall materially reduce the resistance of the return circuit, that it be exceptionally well bonded, otherwise there will be little gained. One point may be noted as being extremely favourable in this class of bonding. The rail is not subject to continuous jar as in the case of rails doing, at the same time, mechanical service, still the joints are subject to the gradual motion of expansion and contraction. The bond must, therefore, be flexible, or it will gradually work loose. If such a feeder were laid with its joints staggering those of an active rail and cross bonded thereto, the failure of a bond on either rail would be provided for. By drawing a sketch of the two rails and the bonds, it will be seen that by staggering the rails each joint is bridged by a rail, the path having four bond joints. If the joints are opposite, the number of bond joints in this reserve bridge is increased to six. The use of old rails for this purpose would seem to be very advisable, being both economical and durable. The electric continuity of the bond may be preserved from corrosion by imbedding it in an asphaltic compound.

Horatio Allen

THE ENGINEER, ON ITS TRIAL TRIP, OF THE FIRST PRACTICAL RAILROAD LOCOMOTIVE IN AMERICA.

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CASSIER'S MAGAZINE.

VOL. X. OCTOBER, 1896. No. 6.

THE VERTICAL ENGINE FOR STATIONARY PURPOSES.

By Charles H. Manning, U. S. N.

IT is quite evident that the vertical, inverted type of engine is rapidly coming to the front for large stationary power plants. Until the rapid development of the use of electricity in the last few years the largest uses of the stationary engine was for textile mills, water works, rolling mills and mining, about in the order named, but it is the first of these uses I am chiefly interested in discussing.

The large cotton mills, starting first with water powers, soon outgrew that source of power in the dryer months of the year, and it was found necessary to supplement the water wheels with steam engines of large power, to be used but a few months in the year.

Amongst the first large engines installed for this purpose, forty years ago, were several double-beam engines, some of which may be working to-day, as is the single beam engine which has run at the Corliss Steam Engine Works at Providence, R. I., for about fifty years and looks as though it might go another fifty.

These engines, as well as the horizontals, either single or in pairs, were proportioned for the lower steam pressures, fifty pounds per square inch or less, in vogue in those days, and have mostly disappeared with the gradual increase of pressures and speeds of the present time. About the last of the beam engine type was the one erected by Mr. Corliss for the Centennial Exhibition at Philadelphia, in 1876, and it was there also that the diametrically opposite type of engine, the high-speed shaft governor type, exemplified by the Buckeye, first attracted general notice in the engineering world.

About this same time marine steam engineering which, of necessity, has always been the leader in improvements, had fully demonstrated the economy of higher pressures and multiple expansion, and stationary engine builders were not long in following suit.

With the compound engine and the demand for larger units of power, from fifteen hundred to two thousand indicated horse-power, came, of necessity, the large cylinder, and as the horizontal type, either cross-compound or tandem, was adhered to, we had pistons of from fifty to sixty inches diameter, and from four to six feet stroke, travelling back and forth from six to eight hundred feet per minute in the cylinders, with the

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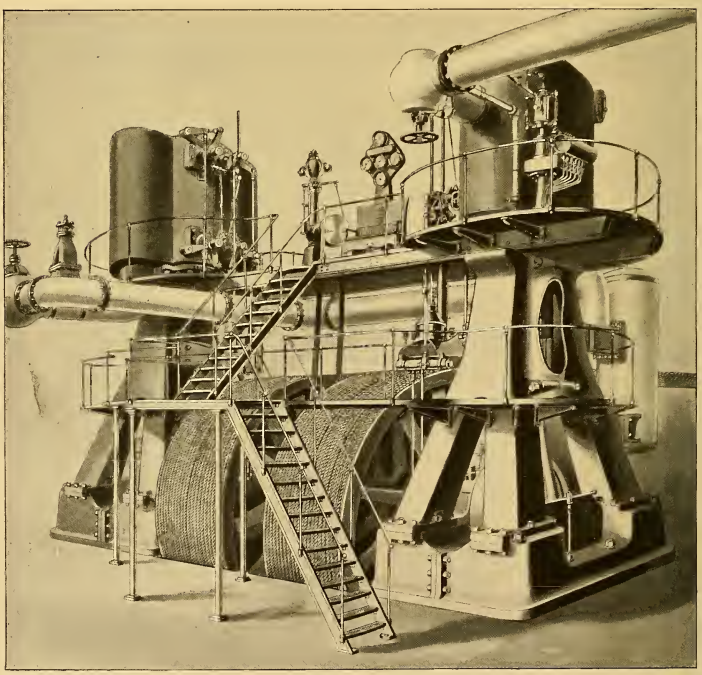
consequent great wear and tear of packing, "bull rings" and cylinders, to say nothing of the barrels of cylinder oil expended in the too often vain attempt to keep then from cutting.

Few designers have taken into consideration that the weight of the piston increases nearly with the square of the diameter, and that if it is to be run on its side, the supporting surface should be increased in a like ratio, so that there are very few of these large cylinders that have not been a source of anxiety and expense from the day they were started.

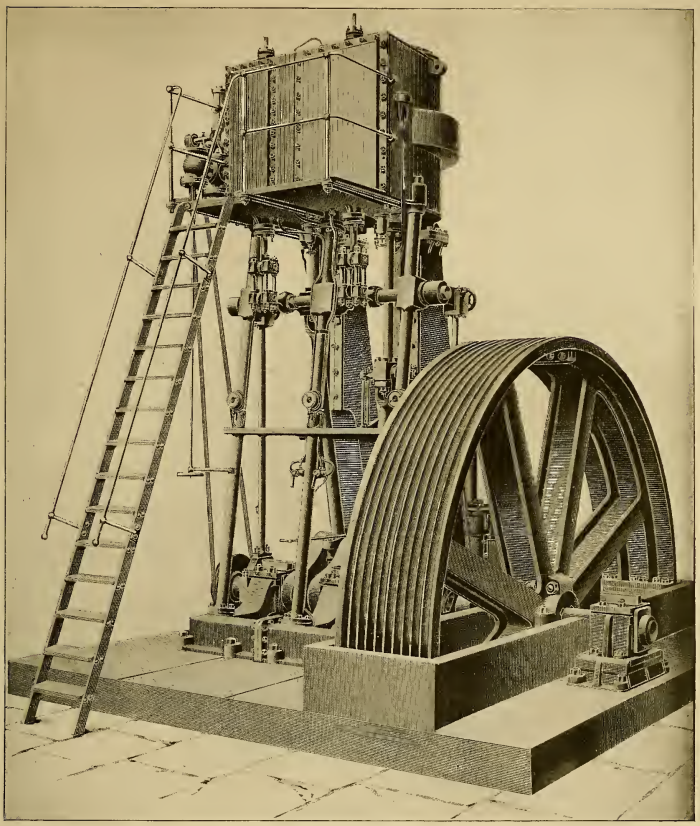
In the naval services in the days of wooden ships, it was necessary for safety to use the horizontal engine and the same difficulties were encountered there. To overcome this, the "tail rod," running through the back head, and the "half-trunk," extending out in the same way, were resorted to quite extensively in the English and French services, but in the United States Navy lighter pistons, made of bronze, and deeper rings, found much greater favour.

The merchant marine, having no shot and shell to dread, has almost always, both with side wheels and screw propeller, used the vertical engine, and trouble with scratched or cut cylinders is a thing almost unknown in its engines. With the protected hulls of modern war ships the vertical engine was largely adopted and it is safe to say that the splendid results of speed



BY COURTESY OF "POWER."

A VERTICAL COMPOUND MILL ENGINE, BUILT BY THE RICE & SARGENT ENGINE CO., PROVIDENCE, R. I., U. S. A. CYLINDERS, 28 AND 60 INCHES DIAMETER. STROKE, 48 INCHES. 100 REVOLUTIONS. HORSE-POWER, 1800.

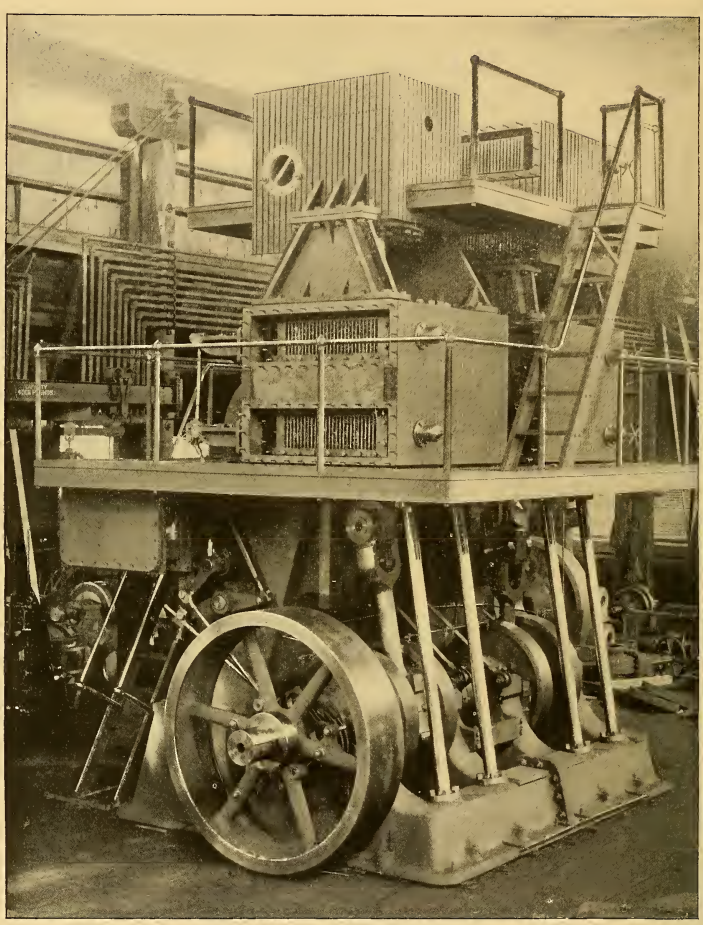


400 HORSE-POWER COMPOUND ENGINE. BUILT BY MESSRS. ROSS & DUNCAN, GOVAN, ENGLAND. CYLINDERS, 19 AND 33 INCHES. STROKE, 48 INCHES.

never could have been obtained with the old horizontal back-acting engines.

With their surface condensers returning all the condensed steam to the boilers, if cylinder oil was used in these engines with the liberality that it is in large horizontal stationary engines, their boilers would not last a week, but the fact is that on the large cruisers little or no cylinder oil is used; the cylinder condensation, on account of the vertical position of the cylinders, affords ample lubrication.

But to return to the shore. The great increase in the use of power for the generation of electricity in large quantities, has served to develop large stationary engines, and as such plants are usually in thickly populated districts, where land or floor space is expensive, the vertical engine has received the preference to a great extent; for a given power, it occupies less floor space than any other type. For the same rotative speed and power the cost of building such engines is about equal,



TRIPLE EXPANSION ENGINE AT THE AMOSKEAG MILLS. BUILT BY MESSRS. MCINTOSH, SEYMOUR & CO., AUBURN, N. Y. FOUR CYLINDERS. INDICATED H. P., 2000.

whether the vertical or horizontal type is used, but as builders become used to designing and building the vertical engine, I think the first cost will be in favour of this type.

As to accessibility for repairs and care in running, there is little to choose between them, but with a properly rigged overhead travelling crane I think the matter of overhauling the vertical is the easier, whereas in running, it is doubtless more convenient to have everything on one level.

In the matter of friction, the vertical engine, too, has a great advantage, as the packing, besides its appropriate office of preventing steam leakage past the piston has only to guide it also, whereas

in the horizontal engine it must not only support the entire weight of the piston, but also the pressure of steam, as the "bull ring" generally fits the bottom half of the cylinder steam tight, but allows the steam to enter on top as far as the packing ring. In the vertical engine, on the down stroke of the piston, the weight of the latter adds to the mean effective pressure as much as it detracts from the same on the up stroke, which, of course, can be offset by varying the cut-off on the different strokes, allowing a greater mean effective pressure of steam below the piston than above it.

In the vertical design, the weight of the cross head does not increase the slide friction which is not the case with the horizontal engine when running, with the crank passing the upper arc as the piston goes towards the shaft; and when the reverse direction is used, although the slide is relieved of the weight of the cross head, a worse trouble is introduced, namely, the slapping up and down of the cross head at each end of the stroke.

As an instance of what has been done in cotton mill practice, it is interesting to note that about eighteen months ago it was decided to put in a steam engine at the Jefferson mill of the Amoskeag Manufacturing Company, at Manchester N. H. This mill, of about 62,000 spindles, is driven, when water is available, by three pairs of Risdon water wheels, arranged on one continuous line of shafting which also carries all the main driving pulleys. These wheels aggregate about 2000 horse-power and the shaft revolves at 232 turns per minute. It is near the west wall of the mill, which is directly on the bank of the Merrimack river, and the spring freshets have at times risen five feet above this shaft.

The direction of revolution is with the top to the east, so that to belt on to this shaft and have the driving strand below, as it should be, it would be necessary to place the engine out in the bed of the river. This it was possible to do, but not advisable. If rope driving was to be used, the engine must go there, for in no other way could a rope drive be satisfactorily arranged.

To use horizontal engines, directly connected to the shaft, they would still have to be in the river, or, if placed to the east of the shaft and "run under," the objection which has already been mentioned would obtain.

All things considered, it was decided to use a vertical engine connected directly to the shaft and running, of course, at a speed of 232 revolutions per minute.

The scheme laid out was for a triple expansion engine, using steam of 160 pounds gauge pressure, with four cylinders,—one high, one intermediate, and two low-pressures,—arranged in two tandems with the high and intermediate on top, and the crank shafts coupled with a removable plate, so that the high-pressure cylinder and its low-pressure cylinder, which come next the driving pulleys, could be used separately from the other two cylinders for part power.

This scheme was sent to several firms of engine builders, some of whom shook their heads and concluded that they did not want any of it, but four or five very good offers were made and the contract was finally given to Messrs. McIntosh, Seymour & Co., of Auburn, N. Y. The cylinders are, one of 22½ inches, one of 36 inches and two of 40 inches diameter, and all of 22-inch stroke.

The pistons are conical steel castings; the piston rods and cross heads are single steel forgings; the connecting rods, cross head pins, crank pins and shaft are all hollow, the latter being of nickel steel, forged by the Bethlehem works; the main bearings and slides are water jacketed.

There are separate reheating receivers between high and intermediate, and intermediate and low-pressure cylinders. The exhaust from the low-pressure cylinders passes through a tubular feed water heater to a gravity condenser placed outside the mill wall. The engine was erected during the latter part of last winter. It was in perfect running order on February 29, and on March 2 was under water up to the

stuffing boxes in the unprecedented freshet of that date.

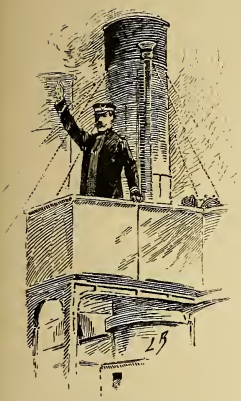
Recovering speedily from this unwelcome baptism, it has been run a considerable part of the time up to date, and though from press of other matters, all the condensation from the jackets and reheaters is still going to waste, and the engine is underloaded by at least two hundred horse-power, the coal per horse-power is 1.38 pounds, including all coal expended for starting and banking fires.

There is no trouble from heating, the regulation is very perfect, and there is no noise or jar; in fact, the result confirms the writer in his belief of years' standing that for large powers there is nothing so suitable as the vertical engine.

A SHOP VIEW OF THE AMOSKEAG ENGINE AT THE WORKS OF THE BUILDERS.

THE NAVAL WEAKNESS OF THE UNITED STATES.

By Wm. Ledyard Cathcart.



WITHIN a decade there has been a complete transformation in the character of the ships which form the United States navy. At the beginning of that period, its fleet was a feeble force of unarmoured cruisers, with but little speed, and carrying obsolete ordnance. The changes since then have been so radical, so extended, and relatively so swift, as to warrant fully the words of *Engineering*, of London, in describing their result as "one of the most remarkable features in the peaceful records of modern navies."

The number of vessels built, or building, during these years is, relatively, not large, but it may be said with justice that the appropriations authorised by the United States Congress for this purpose have been expended wisely and that such ships as the nation now possesses are of high rank in their class. The battle-ships are remarkable for the armour and armament carried on their displacements, for the weight of projectile thrown, the close concentration of gun-fire which is possible, and for their stability as gun-platforms.

They are, however, inferior in speed to some European vessels of their type, —a weakness which Commodore Melville, the engineer-in-chief of the United States navy, opposed strenuously in their design. Years ago, with keen prescience, this distinguished officer gave speed its place as a factor of prime importance; and this, with strong insistence, he has urged as the fleet has grown. To him, speed means position—the "weather-gage" of the old days—and position, with skill and daring, gives success. In forceful words, he has said:—"Speed, and particularly its control, form the cardinal elements of tactics." It is to be regretted, then, that, in these vessels, engine power has been forced to yield to armament and armour.

As to the cruisers, this cannot be said. In the *Columbia* and *Minneapolis* the United States has still the swiftest war vessels of their type, and the record-run of the former across the Atlantic is yet without a parallel in naval history.

The ordnance mounted on these ships, while without especial novelty, is equal to the best in Europe; in armour, America, for a time, led the world and is still in the front rank; and, as to United States naval engines, Fleet Engineer Reginald Oldknow, R. N., pays them, inferentially, a strong compliment when he says:—"From foreign nations, in the matter of machinery, we (Great Britain) have little or nothing to learn, even from the United States." With the quality of its fleet, then, the American nation may, on the whole, be well content.

We have, however, in Captain Alfred T. Mahan, U. S. N., unquestionable authority for the statement that "historically, good men with poor ships are better than poor men with good ships." Ships, their machinery, armour, armaments, crews, and officers' corps, are but the links which, united, form the chain of an efficient naval force; and of these links, this distinguished writer ranks the official personnel as the most vital. A chain has but the strength of

its weakest link; and, in measuring American sea-power, it must be remembered that the cardinal link in its chain has become fragile through thirty years of friction. In the factional strife within the body of its officers of the line, in the now historic warfare waged by a portion of that body upon the staff corps, lies the naval weakness of the United States.

Peace, while the boon of nations, is, in a sense, the bane of a modern naval force. Within a generation, there has been a revolution in the methods and the mechanism of warfare on the sea. During this time of change, no great naval power has found a worthy foeman on whom to test the ability and training of its officers and seamen and the deadly power of the mighty enginery of war which this period has brought forth. And so, year after year, this mechanism grows more involved, complication follows complication, until humanity alone keeps from the student of naval construction the wish that the thundering broadsides of battle would solve some of his intricate problems and sift the wheat from the chaff.

It is in the education of officers that this uncertainty is, perhaps, most severely felt. Navies are, of all institutions known to men, the most isolated, conservative, and hide-bound by precedent and tradition. In the United States especially, have these influences dominated. For a score of years after the Civil War, its fleet steadily became feebler and more obsolete; and yet, during these years, and to this day, there has been maintained a corps of line officers, far in excess of its needs, and skilled only in the arts of navigation and ordnance which they used so ably in that war, while engineering has given to naval science appliances undreamed of then, and has invaded even the field of duty which these officers fill.

And so, we find, while the United States navy, in its awaking, has become almost wholly an engineering service, that old methods still hold sway and that there still prevails an antiquated organisation, which one brief naval war would rudely shatter. On January 1, 1896, there were afloat in the war vessels of the navy 415 line and engineer officers, of whom the latter formed but 22.4 per cent. When it is remembered that these ships are filled with intricate mechanism, not only for propulsion, but for every service which makes a war vessel formidable; that, while line officers operate some of these devices in action, engineer officers only are trained in the knowledge of their construction, repair, and maintenance; and that the removal of this 22 per cent. of engineers would leave the remaining 78 per cent. of this official complement helpless to steam a fathom, to load or train a high-powered gun, or, indeed, to exist on these ships, the absurdity of such a system of naval education becomes manifest.

Long ago, in the shock and stress of a great war, Gideon Welles, in many respects the ablest naval secretary Amercia ever had, realised this. In his official report for 1863, we find:—

"It is a question, indeed, as sails are subordinate to steam, whether every officer of the line ought not to be educated to, and capable of, performing the duties which devolve upon engineers."

And, in 1864, we find him repeating and emphasising these words, thus:—

"It is respectfully submitted, in view of the radical changes which have been wrought by steam as a motive power for naval vessels, whether steam engineering should not be made to constitute hereafter a necessary part of the education of all midshipmen, so that in our future navy, every line officer shall be a steam engineer. * * * Seamanship and steam engine driving will each be necessary to make the finished professional officer. * * * The remedy for all this is very simple, provided the principle were once recognised and adopted of making our officers engine-drivers as well as sailors. * * * Objection may be made that the duties are dissimilar and that steam engine driving is a specialty. The duties are not more dissimilar than seamanship and gunnery, etc."

In his day, practically the only mechanism was that for propulsion; its

vast increase since then, for other uses, but adds force to his wise words.

It is neither, however, with the education, nor with the internal strife of the line of the United States navy that this paper is chiefly concerned. It has been shown that the vital need of that navy is a strong body of officers, of the line or staff, who are skilled in engineering. For the present, this want could be filled most readily, perhaps, by a sufficient increase in the corps of engineers. Such an increase is, however, bitterly resisted by a large body of the officers of the line who fear that their historic prestige will be lessened and who seem ignorant of, or careless as to, existing engineering needs.

There seems to be an ample revelation of the methods which this ignoble warfare has developed in an open letter, entitled "Queer Doings in the Navy," addressed by Mr. Asa M. Mattice to the Hon. Francis H. Wilson, a member of the naval committee of the United States House of Representatives, who has shown marked zeal and ability in advocating legislation for the reorganisation of the corps of engineers on a modern basis. Mr. Mattice's right to speak consists in his graduation, with distinction, from the United States Naval Academy in 1874; in his service of sixteen years as an engineer officer; and in his wide experience during that period—in active cruising at sea, as instructor at the naval school for three years, and for three years also in Washington as assistant to the engineer-in-chief. In this letter Mr. Mattice brings forward a large amount of evidence in support of statements, in part as follows:—

That "the navy is managed practically by a certain clique of line officers, better versed in the arts of intrigue than in their own profession, who have, by hook and by crook, so managed to gain control of affairs that they are enabled to run the navy so as to further their own interests rather than the interests of the country."

That "they (the alleged clique) have not only decreased the efficiency of the engineering branch of the service by cutting down that corps to such a small number as to make it impossible to perform their duties properly, but they have decreased the efficiency of their own (line) corps by increasing their numbers to such an extent that they are unable to get enough practice in the duties of their profession."

That "discrimination is made against the engineers of the navy by reason of their rank being, technically, only relative," and that "perhaps the best illustrations of unjust discrimination can be found in the results of trials by court martial."

In reviewing these charges, we shall consider the evidence accompanying them, and shall present further facts of importance from the United States Naval Regulations and other sources.

I. As to the Alleged Ruling Clique.

The Navy Register for January 1, 1896, shows that there were then on duty in Washington ninety-three officers of the line, a number equal to more than one-half the total strength (173) of the corps of engineers on that date. Since, at this time, the number of line officers on the home and the four foreign squadrons ranged from twenty-eight on the South Atlantic to seventy-seven on the Asiatic station, it is apparent, that, with the relatively small American fleet, such a force at the capital is excessive.

In investigating the services assigned these officers, we find three acting as aids to the secretary and assistant secretary of the navy, which duty, at the most, must be but general; four are in the office of the judge advocate general, where the work is purely legal; five in the library and war records office, where it is literary and clerical; and nine in the office of naval intelligence, whose task is the compilation of information as to naval science obtained at home and received from abroad.

As to these twenty-one positions, it may be said that, as a rule, they were formerly either filled by civilians, or did not exist, excepting some of those in the naval intelligence office, in regard

to which Mr. Mattice notes:—"Ten years ago it gave employment to three line officers and one engineer, now it requires nine line officers and no engineer." It would seem that this office is somewhat indifferent as to the present position of engineering in its relation to naval warfare.

We find, in addition, two officers in the bureau of yards and docks, whose function pertains almost solely to civil engineering and two more on the steel board, whose work is that of mechanical engineers. The remaining sixty-eight officers are distributed in varying numbers through the Washington Navy Yard and the different bureaus and offices. There are, for instance, eleven in the bureau of navigation and eight in that of equipment, which numbers seem large indeed when it is considered that much of the work of these bureaus is routine and clerical and when they are compared with that of the engineer officers—ten, including the engineer-in-chief—who are stationed in the bureau of engineering and by whom the steam machinery of the new navy is designed and the other duties of that bureau are performed. It has been estimated that the cost of graduating a cadet from the United States Naval Academy is about $18,000; it cannot be for economy, then, that line officers are employed in clerical duty.

Certain publications issued in Washington throw some light on the occupation—partial at least—of a portion of these officers. Among them may be mentioned the "Argument of the Naval Association in favour of the Bill H. R. 5215, to improve the efficiency of the personnel of the Navy" (8 vo., pp. 24); "An Argument by the Naval Association in relation to House of Representatives Bills Nos. 790 and 2915 and Senate Bill No. 349, on the Reorganisation of the Navy" (8 vo., pp. 16); and the "Argument of the Naval Association in relation to the Bill H. R. No. 3618 (Senate No. 735)" (Washington, D. C., 8 vo., pp. 51).

The "Naval Association" represents one of the two main factions of the line of the navy. The first "argument" is in favour of a bill drawn mainly to further the promotion of the members of this "Association;" the second is against a bill introduced through the efforts of the main opposing faction; the third is against the pending bills for the increase of the corps of engineers and merits especial attention.

Its text begins:—"The Naval Association presents the following reasons against the enactment into law of the Bill H. R. No. 3618 (Senate No. 735);" it is accompanied by a circular which states, in part:—"The undersigned respectfully urge a reconsideration of any support of the mixed bills referred to above." This circular is signed by thirteen line officers as a committee of this association. Of these officers, eight were on duty in Washington on January 1, 1896, and the list is headed, fitly enough, by a commodore who has had but fourteen years, three months' sea-service out of a total service, to that date, of forty-four years, three months; and finally, the value of this document as an "argument" may be measured from the wholly untrustworthy statement to be found on page 34, as follows:—"It has been shown already that there is no scarcity of naval engineers, nor any probability of such scarcity."

In this connection, it is of importance that attention be directed to Art. 235, of the navy regulations, which prohibits any person belonging to the navy from any "attempt to influence legislation, in respect to the navy, otherwise than *through*, and *with* the approval of, the department." These pamphlets were not issued "through" the navy department and they contain, apparently, no statement that they have its "approval."

There seems to be abundant evidence to warrant the belief that there is maintained at the United States capital, where legislation is enacted and legislators can be approached, a force of line officers far in excess of the nation's needs; that this force is engaged largely in clerical, legal, and other non-professional occupations; and that a part of it, at least, is employed, openly and in

seeming defiance of the naval regulations, in attempts to influence naval legislation, both in furthering its own interests and in attacking those of others whom it may see fit to oppose.

The secretary of the navy is usually a skilled lawyer— never a sailor nor an engineer. Naval organisation and administration abound in obscure technicalities, and, hence, this official must rely largely on naval officers for information, advice, and the execution of his orders. No matter how upright or able he may be—and few American secretaries have been otherwise—the numberless details of his office and his environment are such, that, unwittingly, he may permit, or directly authorise, action to the prejudice of officers or corps.

Congress enacts laws for the government of the navy; on these, as a foundation, the secretary, nominally, makes regulations. The fundamental statutes relating to the matter are relatively few; and yet the present navy regulations, issued in 1893, comprise 1876 articles, with numerous paragraphs, and form an octavo volume of 482 pages, the subject having been elaborated with indefinite detail.

The revision of these regulations is entrusted, from time to time, by the secretary to a board of officers, always wholly or in majority of the line. The board engaged at present in this work is composed of two line officers and the chief clerk of the department, a civilian. It will be observed, that, while the officers of the line do not make the basic laws for the navy, they revise the regulations which are, in effect, its governing laws—bearing to the original statutes a relation somewhat analogous to that between the laws enacted by Congress and the United States constitution. It will be observed, also, that these regulations are not necessarily legal; they represent, at the best, but the views of this board as to what the law directs or as to what it, or the secretary, will permit.

Let us observe the course of an appeal from these regulations. From them, we quote:—

Art. 5:—"There shall be in the navy department a judge advocate general of the navy," etc.

Art. 23, Par. 4:—"The judge advocate general shall be an officer of the navy or marine corps," etc. At this time he is an officer of the line.

Art. 14, Par. 3:—"It shall also be the duty of the judge advocate general to consider and report upon all matters which may be referred to him by the department, involving questions of law, regulation, and discipline; * * * all questions relating to the meaning or construction of the general regulations of the navy," etc.

Under present conditions, then, any appeal from an oppressive regulation, formulated by line officers, may be referred to a judge advocate general, who is also a line officer. Apparently the line of the navy, at this time, makes not only its governing laws, subject to the secretary's approval, but attends also to the interpretation thereof.

The following regulations indicate the line barrier which lies between the staff of the navy and its secretary:—

By Art. 3 there is constituted a bureau of navigation, whose head is at this time a line officer.

Art. 6, Par. 1, gives this bureau charge of "the promulgation, record, and enforcement of the orders of the secretary to the fleet and to the officers of the navy, except such orders (a limited number) as pertain to the office of the secretary." Under this regulation, no head of a staff bureau, such as the engineer-in-chief, can detail one of his own officers to any duty. He nominates the officer, but this bureau may refuse to issue the order and an appeal to the secretary is met by its opposition.

Art. 6, Par. 3:—This bureau "shall establish the complement (crew) of all ships in commission." The engineer-in-chief can only advise, under this, as to the number of machinists and firemen which a certain ship shall have; he is powerless in fixing its force.

The far-reaching powers of this line bureau are still further indicated in the following, which has replaced Par. 11

and 12, Art. 6, since the revision of 1893:—

* * * "All official communications between the navy department and its officers and ships in commission for sea-service which refer to the movement of ships, to their condition, to their repairs, to their availability for sea-service, and to their personnel, shall be forwarded through this bureau." This gives to it the practical control, in detail, of the ships afloat with their officers and men, of every corps and department. There are few communications, if any, from cruising ships to the secretary, or the reverse, which do not pass through its office. The staff is, in this, completely in line hands.

It will be observed that the regulations just quoted place the personnel of the navy generally under the control of the line bureau of navigation. To this provision is due what seems to be a most flagrant act of injustice to the corps of engineers and to the country. From the entry into office, in 1887, of the present engineer-in-chief, there came from him, year after year, in his official reports, strong representations to the secretary and to Congress in regard to the depleted ranks of his corps. These were displeasing to officers who were desirous of weakening, not strengthening, that body; but no method of repressing them was found until, in 1893, there was discovered, in a law relating to the public printer and passed in 1884, the following:—

* * * "Nor shall the public printer print any document or matter of any character whatever, except that which is authorised by law and necessary to administer the public business; nor shall any bureau officer embrace, in his annual or other report to be printed, any matter not directly pertaining to the duties of his office as prescribed by law." (Public Printing and Binding Act of July 7, 1884; Stat. 23; p. 227.)

This, with the personnel provisions of Art. 6, settled the matter; and, from 1893 onward, the engineer-in-chief has been "muzzled," as the daily press, at that time, characterised it. The need of his corps may be desperate and the danger to the nation imminent, yet the engineering head of the navy must be silent before the secretary and before Congress, since a board of line officers has placed his personnel in the hands of what seems to be a usurping bureau of the line. It is difficult to speak with moderation of this act.

The following is a minor instance of the same nature:—

Art. 1609, Par. 5 (substituted since 1893 revision):—"Captains of ships shall conduct all correspondence with their commander-in-chief or with the navy department upon all matters of detail relating to their command. Letters of heads of departments of the ship, upon such subjects, shall be addressed to the captain, who may, as he deems best, either forward the original with a proper endorsement, keeping a copy of both letter and endorsement, or write a separate letter and retain the original on the ship's files."

That is to say, the chief engineer, who is one of the "heads of departments," and has under him several officers and from 25 to 60 per cent. of the ship's complement, writes a letter referring to the machinery or to this force. The captain is permitted by this article to retain this document and, if he deems best, to write one in place of it opposing diametrically the views which it contains.

The evidence as to the existence of the clique of line officers, which, it is alleged, controls the United States navy, seems to be somewhat formidable. We have first a civilian secretary, who, with the other grave duties of his office, finds his four years' term all too brief to grasp fully the details of naval administration and the ramifications of naval chicanery, if it exists.

At Washington, we find an absurdly large force of line officers, many with legal, clerical, and other non-professional occupations, and some engaged openly in attempts to influence naval legislation. These fill all avenues to the secretary and form a cordon of outposts about him.

There is then a powerful line bureau,

wide spreading as a great octopus, reaching to every office and to every ship, and through which the bulk of the secretary's correspondence with officers passes to and fro.

We find the engineer-in-chief without power to detail one of his own officers, or to determine the engineers' force of a ship, or to speak in his report of his own personnel.

We find the line of the navy revising the internal regulation of that service; interpreting them when they are appealed from; as executive officers, enforcing them; and as will be hereinafter shown, acting as judge and jury, when, in their opinion, these rules are infringed.

The founders of the American republic drew wide bounds between the legislative, judicial, and executive functions of its government. Is it reasonable to suppose, that, at any period in the history of Congress, it would have authorised, *en bloc*, any such combination as the system which has been outlined above? Why, then, does it exist? How has it grown? Let its builders answer. The very completeness of the results which have been attained, seem to prove organised effort extending over a long period of years.

II. Undue Reduction of the Corps of Engineers.

If, as is alleged, a clique of line officers has controlled, in effect, the United States navy for years, it needs no demonstration to prove that the corps of engineers must be especially obnoxious to this clique, since, with the vast advances of engineering in naval warfare —not only in propulsion, but in navigation, artillery and torpedo service, lighting, ventilation, etc.—that corps must constitute, necessarily, the most formidable foe to the continued supremacy in the navy of the line, and, hence, to the power of this alleged clique. Let us consider, then, some points in the history of the engineer corps since the Civil War.

From Mr. Mattice's data, we learn, that, in 1864, during that war there were, in the regular and volunteer service, 2846 line officers and 1728 engineers, a ratio of 1.64 line officers to each engineer. "These numbers had been fixed by the necessities of war, and it is by reason of wars that navies exist." In 1866, just after that war had ended, there were left in the regular service 395 line, and 379 engineer officers, a ratio of 1.04 to 1. The Navy Register for January 1, 1896, shows 715 line officers and but 173 engineers, a ratio of 4.13 to 1. Since 1866, then, one corps has grown and the other has been reduced until, in 1896, we find over 80 per cent. more line officers, with the engineer officers decreased by 55 per cent.

From this, one might fancy, that, during these years of peace, naval engineering had slept, or rather that it was a dying science. Exactly the reverse is true; it has gone forward with giant strides. The horse-power of the United States naval vessels has grown from the maximum of 1000 in 1864, to the 20,862 of the *Minneapolis* to-day. The era of the compound engine has begun and ended, and the triple and quadruple expansion stages have been reached; boiler pressures have advanced from 40 pounds to 160 pounds and upwards; the single screw-propeller has given way to the twin and triple forms; there have been introduced forced draught, air-tight firerooms, and the separation of the machinery into compartments; and the half dozen auxiliary engines of the monitor have grown into a mass of machinery thus classified, which in the *Columbia*, for instance, comprises 91 separate engines with 171 steam cylinders.

As has been noted previously in the pages of this magazine, the United States naval regulations require engineer officers to inspect and keep in repair all of this so-called "auxiliary" machinery which has so many varied functions in propulsion, navigation, artillery service, etc. These officers are, hence, neither steam nor propelling engineers merely; but are, necessarily, experts in the designing of steam machinery and in the construction, operation and conservation of steam,

electric, hydraulic, and pneumatic mechanism, as applied to naval uses. The field of the engineer in the United States navy is now so wide, that, without his care and skill, not an anchor could be weighed; a helm swayed; a hull manœuvred; a high-powered gun loaded, elevated, or trained; a torpedo discharged; a search-light flashed; or the heating, lighting, and ventilation of the ship secured.

The persistence and audacity of the efforts to reduce the corps of engineers were shown notably in the illegal dropping from the service of twenty-nine cadet engineers at their examination preparatory to the receipt of commissions. This was done under a false interpretation of the act of Congress of August 5, 1882; and Mr. Mattice notes, that, despite decisions in their favour by the Court of Claims and the United States Supreme Court, the return of these officers to their proper position and rank in the service was resisted successfully until 1888, when a special act of Congress to that effect was passed.

It is not to be supposed that these repeated reductions have been effected without protest. Time and again those who know the danger to a navy, in this respect so under-officered, have given forceful warning and have made strenuous appeal. In his first report,—that of 1887,—after his entry into office, the present engineer-in-chief said:—

"The whole number of engineers in the service on the first of October of this year (1887) was 223. * * * The bureau being already embarrassed in the assignment of officers in such a manner that the machinery of vessels in commission may be properly cared for and, at the same time, the multifarious duties on shore properly attended to, it is difficult to foresee what is to be done when the personnel of the engineer corps becomes reduced to the legal limit of 170. * * * I would recommend that, if possible, the number of passed assistant engineers should be increased to the former number of 100."

These statements were repeated, year after year, with more insistence, as the need became more urgent, until, in his report for 1893, we find this distinguished officer saying:—

"There are at this date (September 29, 1893) 180 commissioned officers on the active list of the engineer corps of the navy. * * * Were the navy a mercantile concern the present state of affairs would not last beyond the time necessary to change it, for men with capital invested in machinery see to it that there is a force sufficient to keep it in proper maintenance. * * * The value of the naval machinery now owned by the government, and in process of construction, is about $24,000,000 and it has now come to the point where Congress must decide whether it is more economical to properly care for this machinery and keep it always in an efficient condition, or to let it run on as long as it will and then replace it, taking meanwhile the risk of having it fail when most needed. * * * The officers of the engineer corps at sea on the new vessels have altogether too much work to do now. * * * The result of this hard work is being seriously felt; retirements are increasing and the government is thus subjected to an expense greater than would be involved in now granting a fair increase of numbers, while some of those who manage to complete a cruise in one of the high-powered ships only await a favourable opportunity to resign."

These strong and frank words were bitterly resented by the opponents of the engineer corps; and, after this date, we find no mention of the matter in the reports of the engineer-in-chief, his voice having been silenced as to this, the most vital need of the navy, by methods which have been noted previously herein. In 1891, in his annual report, the secretary of the navy said:—

"The report of last year (1890) pointed out the necessity of congressional action in reference to the naval personnel, both of the line and engineer corps. * * * It was then stated that there were not at the time "enough engineer officers in the navy for ordinary working purposes and if no additional ships were built an enlargement

of the corps would be necessary." A modern man-of-war is a vast and complex machine, needing intelligent and trained minds to insure a perfect working of the parts, failure in any one of which may be fatal at a vital moment. * * * It is false economy to put in our new vessels all that is most advanced in high-pressure machinery and the multitude of engines and devices by which steam and mechanical appliances are made to do the work of man, and then to provide an insufficient number of officers to control them."

On April 20, 1892, the committee on naval affairs of the Senate, in reporting favourably a bill to increase the corps of engineers from its then strength, 189, to 303, said:—

"It will be seen that the total number for supplying effectively the demands of the navy for sea and shore duty is 303, an increase of 114. * * * In view of the increase in the number of war-ships, completed, and provided for, * * * your committee is of opinion that this number, added to the engineer corps, of the navy is not only not excessive, but necessary to meet the requirements of the service."

And, finally, the present American ratio of 4.13 line officers to one engineer officer is notably excessive, when compared with that of the most powerful navy of the world. Great Britain, Mr. Mattice states, has "1730 line officers and 795 engineers, a ratio of 2.18 to 1, or nearly twice the proportionate number of engineers," and yet in its issue of February 7, 1896, *The Engineer*, of London, says:—

"We have not engineers enough for the ships we now have; whence are they to be had for the large additions that must be made to our fleet?"

And again under date of May 15, 1896, this journal states:—"The admiralty * * * admit that there is not a sufficient number of engineers available to supply all our ships."

In view of the relatively large proportions of the corps of engineers in the Civil War; of its ever widening field since then; of its meagre numbers now; of the strenuous efforts of successive engineers-in-chief to resist repeated reductions; of the favourable views regarding its expansion which are indicated in the typical quotations, cited from official and congressional sources; of the marked disparity, both relative and actual, between the engineer staff of Great Britain and that of the United States; and of the steady and growing demand of the American press, both professional and lay, that this arm of the service shall be strengthened, the conclusion is inevitable, that, in these thirty years of peace and politics, the reduction of this corps has been effected, and a proper increase is now resisted, by such organised opposition of a body of officers of the line as has been already referred to in the printed and audacious "Argument of the Naval Association" of the line against the bills now pending for the increase of the corps of engineers.

III. Undue Increase of the Line Branch.

As to this, Mr. Mattice says:—"We find, that, while there are only seventy chief engineers in the navy, there are 130 commanding officers—an anomaly which appeals directly to one's common sense. Of the forty-five captains, we find only eighteen at sea. Of the eighty-five commanders, we find only seventeen at sea. We also find such anomalies as a commodore who has had but 14 years 3 months' sea service out of a total service of 44 years, and another with only 13 years 4 months' sea service out of a total service of 43 years. The senior captain has had but 2 years' sea service out of nearly 12 years in his present grade. The next captain has had 3 years' sea service out of 11. The next one, 2 years 2 months out of 11 years; the next one, 1 year 11 months out of nearly 11 years, and so on. The senior commander has had only 3 years' sea service out of over 14 years in his present grade. The next one only 4 years 7 months out of 14 years. The next only 4 years 5 months out of 14 years. The next only 3 years 11 months out of 14 years. The next only 2 years 6 months out of 14 years,

and so on." This list of sea service reads like the roster of some Oriental fleet; and yet its data are taken directly from the official register of the navy of the United States, issued January 1, 1896.

We find, further, from this register, that, on its day of issue, there were at sea with the home and the four foreign squadrons, on the training ships of the navy, and with vessels on special service or as yet unassigned to a squadron, but 338, or 47.27 per cent. of the 715 officers who formed then the commissioned line of the navy. That even this result was attained only by crowding American ships with line officers, is clearly shown by the following table, which gives the number of commissioned line officers on United States and British vessels of about the same tonnage and horse-power, the data being obtained from the United States Naval Register of January 1, 1896, and the British Navy List of February, 1896:—

	Displacement, Tons.	Line Officers	
		U. S.	G. B.
U. S. Indiana	10,288	10	--
G. B. Anson	10,600	--	10
U. S. New York	8,200	12	--
G. B. Blenheim	9,000	--	10
U. S. Olympia	5,870	11	--
G. B. Vulcan	6,620	--	7
U. S. Cincinnati	3,213	9	--
G. B. Rainbow	3,600	--	6
U. S. Bennington	1,710	8	--
G. B. Brisk	1,770	--	4
Totals	----	50	37

It will be seen that the United States ships have 50 line officers against but 37 on the British vessels, or over 35 per cent. more. While this excess may not be as great in all cases, the marked disparity, in this respect, between the two services is apparent.

To provide for the line officers, who, even with these crowded ships, would be left otherwise without duty, has required much ingenuity and a marked trespass beyond the legitimate limits of their profession. The excessive number stationed in Washington, with their partial employment in legal, clerical, and engineering work, has been previously referred to; engaged in duties elsewhere, which are not entirely professional, we find, on January 1, 1896, eight line officers with the commission of fish and fisheries; twenty-nine with the coast and geodetic survey; nineteen as light-house inspectors and one as instructor at a college. There are, in addition, nine on the staff of the naval war college at Newport, which is in session only in the summer months. The practice of spreading the work over as large a number of officers as possible is, perhaps, most conspicuously shown in the roster of the Naval Academy. The Navy Register for January 1, 1873, shows that in that year there were stationed at Annapolis twenty-nine line officers and 248 cadets; the register of January 1, 1896, shows fifty line officers for 241 cadets. In the interval there has been no increase of moment in the curriculum.

Such a record of inexperience at sea since the Civil War could but have its inevitable sequence in the long list of vessels, lost or stranded during that period, which has given the United States navy such unenviable fame and from which Mr. Mattice cites so many striking instances. The net result of the unwise and unpatriotic policy of overcrowding the line of the navy seems to have been a loss to the nation of many millions of dollars and of not a few human lives. That this is realised to some extent by able officers of that branch, is indicated by the following extracts from the Proceedings of the United States Naval Institute, Vol. XXII, No. 1:—

Commander C. H. Davis, U. S. N.: —"And there is another tremendous abuse, still very dear to us all, which these years produced and made legitimate, so that it is recognised to-day; that is, the abuse of shore duty. Shore duty for sailors,—the very idea is anomalous and absurd. Whenever a naval officer accepts shore duty, or an appointment to shore duty, it should be with a distinct understanding, that, by so doing, he drops out of the line of promotion and accepts retirement."

Captain P. F. Harrington, U. S. N.: —"It is to be regretted that the circumstances of our own navy do not permit officers to spend their lives more continuously at sea. For, mere lands-

men by habit, however extensive their naval thought and acquirements, cannot control a ship under way with that facility which comes only to the practised seaman. * * * We should live more at sea."

These views are, unfortunately, not shared by all of the officers of the line. We find in one of the "Arguments" of the Naval Association, the following:—

"There are grave reasons for maintaining a large number of captains and commanders, even if they cannot be kept continuously in practice in command at sea. * * * Few captains acquire more than 2¼ years' sea service in that grade, or at the rate of not more than one-fifth of their time in the grade. Of the commanders very few have as much sea service as one-fourth of their time in the grade."

In the judgment of the unprejudiced landsman, it would seem that only necessity of the gravest nature would excuse the placing of men, with such scanty sea experience as this, in command of a ship costing several millions of dollars and carrying several hundred human lives.

IV. Court-Martial Justice.

From the many cases noted by Mr. Mattice, we cite the following:—

General Court Martial Order No. 33, April 24, 1894.—The officer accused was a lieutenant of the line. Charge 1, "neglect of duty;" charge 2, "culpable inefficiency in the performance of duty." It was specified that the accused, as navigator of a cruiser at sea, neglected "to personally take an observation for longitude;" to "obtain the local deviation of the compass" on two successive days; and "to advise his commanding officer, as it was clearly his duty to do, to lay a safe course for said vessel." The ship was run upon a bank, was stranded, and became a total wreck.

Finding as to charges 1 and 2 "Guilty;" sentence, as remitted in part, "to be suspended from duty for one year on waiting orders pay, to retain his present number on the list of lieutenants during said period of suspension."

General Court Martial Order No. 43, July 3, 1895.—The officer accused was a lieutenant of the line. Charge, "Culpable inefficiency in the performance of duty." It was specified against the accused, that, as ordnance officer of a cruiser, and, as such "being responsible for the efficiency of the armament of said vessel and of all appurtenances connected therewith, and it being his duty, before every firing, to examine and see filled with liquid the recoil cylinders of the battery, did, nevertheless, neglect and fail to so examine and see filled the recoil cylinder" of a rapid fire gun before target practice; in consequence of which "the recoil and counter-recoil piston rods broke upon the first firing of said gun, and the gun jumped in off the slide and upon the deck, striking the gun captain of said gun," a coxswain, "in the head, crushing his skull and killing him instantly."

Finding "Not Guilty." The secretary of the navy in disapproving the finding and acquittal of the court martial in this case, said:—"It cannot be, that, on board a United States man-of-war, so plain a regulation can be violated and no one to blame. * * * Responsibility and authority go together. * * * If duties are required to be performed in his (an officer's) department of the ship, it is for him to perform them, or see that others do," etc. The secretary, however, had power only to disapprove the finding. The officer was restored to duty.

General Court Martial Order No. 42, May 26, 1894.—The officer accused was a passed assistant engineer. Charge, "Absence from station and duty without leave." Finding "Guilty." Sentence, as finally affirmed, "To be suspended from rank and duty for the period of one (1) year on furlough pay, and to retain his present number on the list of passed assistant engineers during such suspension."

General Court Martial Order No. 67, November 23, 1892.—The officer accused was an assistant engineer. Charge, "Disobedience of the lawful order of his superior officer." It was specified against this young officer,

that, having "received a lawful order from his superior officer, the officer of the deck" (a young lieutenant), "to report to him," he "did refuse to obey, and did then and there willfully disobey said order."

It is not to be supposed that there was actual insubordination in this case. There was apparently a conflict of regulations, and a disinclination, on the part of the engineer officer, to yield to the provisions of Art. 591,—a regulation which will be hereinafter discussed and which seems to have been formulated for the humiliation of the staff of the navy.

Finding "Guilty;" sentence "to be suspended from rank and duty, on waiting orders pay, for a period of one year."

In analysing these cases, we find that the sentence of the passed assistant engineer, for absence without leave, is more severe than that of the navigating lieutenant, whose ship was lost, since the period of suspension was the same with each and the engineer received "furlough-pay" only, which is but one-half of the "waiting orders pay" given the lieutenant. Again, the assistant engineer for his refusal to obey the petty order of his young and temporary superior, was punished almost as much as was this navigator of a wrecked vessel. And, finally, we find the ordnance lieutenant freed from all blame, although a blue-jacket met death through some one's blunder, and the secretary himself was moved to indignant criticism of the reasoning and verdict of the court.

From the marked severity of the sentences imposed upon engineer and other staff officers, when contrasted with those given to offenders of the line branch, it would seem that line officers must stand necessarily upon a higher plane before the law. A consideration of the status of each will show this to be erroneous.

For three years after a lad enters the naval school he is not assigned to any corps; at the end of that period and during his closing year, he pursues special studies to fit him for the line, the corps of engineers, or the marine corps, as his preference or the needs of the service decide. When they are graduated finally, the cadets of the engineer and line divisions receive commissions, the text of which is identical with all.

The same president, in the same time-honoured words, reposes "special trust and confidence in the patriotism, valour, fidelity, and abilities" of each and charges "all officers, seamen, and marines under his command to be obedient to his orders." To the time of entry into commissioned rank, the conditions for all are, then, the same; as to the status of any officer subsequently, it may be said that the Revised Statutes of the United States may be searched from end to end, and in vain, in the effort to find proof that the law regards the line of the navy as a body privileged above their comrades in the service. To reach the solution, one must seek further.

It has been shown previously that in the hands of line officers rest both the interpretation and the enforcement of law and regulation. It will now be shown that these officers form both judge and jury when, in their opinion, either is infringed. In considering the following extracts from the United States Navy Regulations, it will be remembered that these regulations are not the law; they are merely the law as expounded and expanded by the gentlemen who drew them:—

Art. 1780, Par. 1:—General courts martial may be convened by the president, by the secretary of the navy, or by the commander-in-chief of a fleet or a squadron.

Art. 1782, Par. 2:—In detailing officers for a general court martial for the trial of a medical, pay, marine, or engineer officer, it is deemed proper, if the exigencies of the service will permit, that at least one-third of the court shall be composed of officers of the same department or corps as the person to be tried.

Art. 1783, Par. 2:—The limitation as to the number, rank or corps of the members is discretionary with the ap-

pointing power, and his decision thereupon is final.

Art. 1785, Par. 1:—It is entirely within the discretion of the officer empowered to convene a court martial to direct what portions of the complaint against an accused shall be charged against him.

Art. 1791, Par. 2:— * * * All the members have equal rights before the court, and, therefore, when a question shall be raised in the course of the proceedings, the president shall put it to the court, and it shall be decided by the majority.

Art. 1872:—Where the law does not authorise the officer who convened a general court martial to confirm and execute the sentence, he has still absolute power to disapprove and annul it, etc.

The extracts quoted above form but a small portion of the ninety-seven articles, with their numerous paragraphs, which relate to the subject of general courts martial as embodied in the United States Navy Regulations. So sweeping, however, are the powers granted in the six articles cited, wholly or in part, above, that, with but few exceptions, the remaining ninety-one might well have been omitted.

In considering the articles quoted, we note that the president has seldom, if ever, exercised his right to order a naval court; that the secretary of the navy is surrounded by line advisers; and that the commander-in-chief of a fleet or squadron is always a line officer. In the great majority of cases, the convening authority is therefore, really, or in effect, of the line.

As to the composition of the court, we note, that, by Art. 1783, it is expressly stipulated that its membership, as to corps, is discretionary with the appointing power; and since, by Art. 1791, all members have equal rights and voting powers, it may be said, that, in few cases, if any, has the majority of the court for the trial of either a line or staff officer been from the staff, while the case in which there has been even a single staff officer sitting a court for the trial of a line officer, is so rare as to be the exception which proves the rule. Finally, through the provisions of Art. 1785, the convening authority, in formulating charges, can select, for a favoured offender, any portion of the complaint against him, disregarding the remainder; and by Art. 1872, he can favour the offender further by annulling his sentence.

But this is not all. The following regulations, while they are but a logical elaboration of the ruling principle previously shown, are intolerable in a republic:—

Art. 1813, Par. 2:— * * * neither * * * the accused nor any member of the court has any right to enter an exception or protest on the record.

Art. 1849:—Except in the case noted in Art. 1854 (death sentences) the opinion of the majority is the opinion of the court and the minority is bound thereby; but as the oath taken by every member provides for the concealment of the vote or opinion of each particular member, care shall be taken that it does not appear on the record either that the votes of the members in regard to the finding or sentence were unanimous or what number of them voted for any particular finding or sentence, with the exception already noted, etc.

Art. 1854:—Sentences of courts martial which extend to loss of life require the concurrence of two-thirds of the members present, and cannot be carried into execution until confirmed by the President of the United States.

Bearing in mind, that, in few cases, if any, is the majority of a court from the staff and that, in cases of importance, when officers of any corps are tried, those of the staff seldom comprise more than one-third of the members, it would appear, from Articles 1813 and 1849, that the staff can enter no "exception or protest on the record," that "the opinion of the majority is the opinion of the court and the minority is bound thereby," which precludes any minority report; and that even the votes of members as to "finding and sentence" are by the oath taken, to be concealed. By these provisions, staff members are,

in effect, gagged and bound; they are but lay figures on these courts.

It is not surprising to find, as a fitting climax, that Art. 1854, taken in connection with Art. 1783, Par. 2, previously quoted, places, practically, in the hands of the line the power of death sentence on the staff (subject to the confirmation of the president), since, if a staff officer be tried for a capital offense, a two-thirds vote only is required to convict him, while the convening authority, though advised that "it is deemed proper" that at least one-third of the court shall be composed of officers of the corps of the accused, is notified further that the court's constitution, as to number and corps, is "discretionary" with him, and that "his decision thereupon is final."

The laws of the sea have a long ancestry. The principal statutes of the United States for the government of the navy, beginning with the year 1802, follow British practice so closely as to prove fully the common origin of both. In his brilliant and exhaustive work, entitled "The British Fleet," Commander Robinson, R. N., traces this origin backward, through the ages, to the code of the Republic of Rhodes, which code formed the basis of the laws Oléron, adopted by Alphonso X., of Castile. On these laws the British "Black Book of the Admiralty," which contained some ordinances drawn up prior to the reign of Edward III., was largely founded. There followed then the acts of the Long Parliament in 1645; the Articles of War of Charles II., under whose bloody rules, altered and extended in the time of George II., Admiral Byng met death; the amending act of George III., and the naval discipline act of 1847, with its subsequent changes and additions.

It may be contended that a procedure, which is thus the outcome of ages on the sea, should be beyond criticism; but a study of its development reveals, in the main, a steady mitigation of its primary rigour and an increasing restriction of its powers. With regard, then, to the sweeping prerogatives not only of the convening authority, but of the majority of a United States naval court martial, it seems wholly pertinent to ask whether these powers are the due entirely of the military necessities of our time, or whether they are not, in part at least, anachronisms in this age.

That justice, in the abstract, is not wholly absent from these regulations is shown by Art. 1782, which as to the members, provides, in part, that, "in no case, when it can be avoided without injury to the service, shall more than one-half, exclusive of the president, be junior to the officer to be tried." This one-half, with the president, makes a majority of officers senior to the accused; otherwise it might be possible for a majority of junior members to obtain promotion by sentencing, to dismissal, from the service, a senior of the same corps who is tried before them. It will be noted, however, that this provision affects, practically, only the line, since officers of that branch form the majority in all courts.

If, then, the military law of this service can be so drawn as to protect an accused line officer from the greed of unprincipled juniors, why should it not also defend an accused staff officer from the enmity against his corps, by permitting the detail of the majority of the court which tries him from his own branch of the service?

There seems to be no doubt as to the exceeding injustice, as a whole, of the regulations quoted to the staff of the navy, since under Articles 1782 and 1783, these officers form always a hopeless minority. Tradition has it that the court martial is descended from the ancient "Court of Chivalry," established by Edward III., the province of which was the relief of those aggrieved in matters of honour.

The court, in the lapse of ages, seems to have fallen from its high estate; the Chevalier Bayard would scarcely know it now. In the United States navy it seems to have become but the facile instrument of a military oligarchy within the line of that service. It has been said, as to a great land, that its government was "a despotism tempered by assassination;" it is fully time that the

despotism, formed and fostered by such regulations as are herein cited, shall be "tempered" by the force of public opinion.

The total number of line officers in the United States navy is (January 1, 1896), 715; the officers of the staff, of all corps, number, with the marines, 583. While these officers are all equal before the law, we find, under a system which must be odious to fair-minded men, that nearly one-half of them are practically at the mercy of the remainder. These proportions, too, apply only to times of peace. In warfare, with an engineer corps equal to, or greater, than the line and with the other staff corps proportionately increased, the staff, as a great majority, would be tried and sentenced by the line, as a small minority. There can be no claim of military necessity advanced in support of this, since the line branch has furnished the most noted, if not the only, case of mutiny among officers, as it has also of officers tried for cowardice. To this system may be traced that mockery of justice which has made, from the records of not a few general courts martial, a roll of dishonour to the navy of the United States, and which has drawn forth, from an able writer, such condemnation as this:—

"The practice violates the principles upon which our judicature is founded and the constitutional rights guaranteed to every citizen, an impartial trial. The constitutional guarantee for trial by jury is violated, and an arbitrarily selected court is organised by the will of a single individual, who frames charges, reviews the proceedings, approves the sentence, and executes it. The practice is a monstrous barbarism in our republic."

The evidence set forth herein is but confirmatory of that presented by Mr. Mattice; his charges seem established.

V. Other Ex-Parte Regulations.

Passing now from the consideration of his able and vigourous letter, we shall consider other regulations in which seeming injustice is done. Take, for instance, the question of rank.

In 1871, Congress established staff rank, as it is now held. The legislation was somewhat unsatisfactory, owing, apparently, to a misunderstanding as to the technical use of the terms "rank" and "grade." The discussions in Congress show clearly the intention of the law makers; the regulations for the government of the navy show that those intentions were defeated. Senator Cragin, for example, said that the "relative rank" granted was intended to give "staff officers equality in everything, except what pertains to actual command;" that the term "command," as thus used, applied only to ships, fleets, and naval stations, is clearly shown by the words of Mr. Stevens, who stated in the House, that, in the opinion of his committee, "this bill conferred upon the staff of the navy the same rank and official position that are enjoyed by the staff corps of the army."

Now, the staff corps of the army have actual, not relative, rank; and yet, while a more complex organisation than the navy, the engineer-in-chief notes that "the army moves along with an exhibition of mutual respect and good comradeship which speak volumes." Actual rank, as in the army staff corps, was, then, what Congress intended to confer. Let us observe the respect given these good intentions by the navy regulations:—

Art. 20 prescribes the "relative rank" of staff officers of the various grades and corps. In Art. 23, Par. 2, is clearly shown the department's estimate of this rank. It states:—"A captain or commander, when chief of a bureau of the navy department, shall have the relative rank of commodore, during the time he holds such office, but his actual rank and title shall remain unchanged." That is to say, the captain or commander, while holding the relative rank of commodore, has not the powers of that grade, such rank being but an empty honour.

This construction is carried out in detail through these regulations. The crew of a man-of-war is divided into gun, powder, and engineer divisions, etc., the arrangement being such as to

meet the presumed requirements of battle. By Art. 581, we find that the ordnance officer, a line officer, "shall command the powder division." Art. 714, Par. 3, says that the chief or senior engineer "shall, at quarters, take charge of the (engineer) division." We have then the officer of the line commanding his division while the engineer officer is simply to "take charge" of his, although, in a broad sense, both perform practically the same military duty. The difference in words seems trifling, but its effect, in a military organisation, is far-reaching.

The engineer division consists of from 25 to 50 per cent. and upwards, of the crew, the remainder of the complement being divided into line divisions as above noted. The quarters for officers below the rank of captain comprise the ward-room, which has individual state-rooms, and the junior officers' quarters which have not these, and other conveniences. Art. 1069 defines ward-room officers as only those "above the rank of ensign," except when "ensigns" are "assigned to duty as watch and division officers."

By Art. 714, the engineers' force, with all its officers and men, constitutes but one division only, which can have, therefore, but one division officer, the senior engineer. The actual, and intentional, effect of these provisions is to give to an ensign, who commands a small line division, the privileges of the ward-room, while the junior engineer officers of that rank, though, perhaps, graduated previously from Annapolis, are crowded into junior quarters with naval cadets. The following regulations, when considered together, show, at the least, grave inconsistencies:—

Art. 54, Par. 5:—"The officer in command of a ship of war is not authorised to delegate his power, except for the carrying out of the details of the general duties to be performed by his authority. The command is his, and he can neither delegate the duties of it to another, nor avoid its burdens, nor escape its responsibilities," etc.

Art. 54, in its introduction, defines the executive officer as, next to the captain, the senior line officer "who, for the relief of the captain, and by his (captain's) authority alone, carries out, on board the ship, the details of organisation, inspection, and police."

Art. 591:—"Every officer or other person in the ship, whatever may be his rank, who is subject to the orders of the captain, except the executive officer, shall be subordinate to the officer of the deck."

The officer of the deck of a naval vessel is the officer, who, for the time, has charge of her, at sea or in port. He may be a gray-headed lieutenant of long experience, or a stripling ensign with practically none. By Art. 591, we find absolute power, except as to the executive officer, placed in his hands, and yet, in Art. 54, Par. 5, it is shown that the captain has no authority to delegate this power, except in routine matters.

The executive officer has charge of what is practically the house keeping of the ship, with the infinite detail of which the officer of the deck is continually in contact. If the latter is to relieve the captain of routine, the executive is the one man who should be most frequently summoned for consultation with, or orders from, the officer of the deck. Why then is this officer excepted, while the chief engineer and other staff officers, who may be his seniors, are made temporary subordinates of the officer of the deck?

The apparent conflict of these regulations has, seemingly, but one explanation. It is not intended that the captain shall delegate his authority on any essential matter; in details only can he transfer it to the executive officer, who is usually of long experience. This officer cannot be summoned by the officer of the deck; the latter seldom sends for any other of his corps who may be his lineal superior; and thus a senior of the line branch is practically free from the unpleasant duty of reporting to his junior. It is not so, however, with the staff; and under the provisions of Art. 591, many a medical, pay, or engineer officer, of long service and high rank, has been ordered to the quarter-deck by a man, a score of years younger, on

business, which, if with the executive, would have been transacted through a messenger.

Art. 591 seems to have no logical ground for its existence in so sweeping a form; it is intended apparently, under the conditions above recited, to humiliate the staff of the navy.

Art. 711, Par. 1, states that the senior engineer "shall, from time to time, make inspections of steam machinery under the cognisance of other bureaus and report to the captain any repairs or adjustment which, in his judgment, may be needed. He shall have immediate charge of all such repairs," etc. The "other bureaus" referred to, are represented on shipboard by officers of the line. The purpose of this regulation seems to be to give the line branch a fictitious importance at the expense of the corps of engineers, since the former corps is given charge of machinery which it is unable to adjust and repair.

A similar principle is carried to an absurd extent in the following:—Art. 547 makes coal a part of the stores of, and therefore under the control of, the line bureau of equipment. The executive (line) officer represents this bureau on shipboard and he is directed, when it is received, to enter it on his books and then to transfer it "immediately" to the engineer department. Art. 713 directs that the senior engineer "shall keep an account of the expenditure of coal for various purposes and shall furnish the executive officer with such information as he may desire for making the required coal report," presumably to his bureau of equipment. Coal is one of the largest items of expenditure in a cruising vessel; and in order that the amounts appropriated for this purpose may remain under the control of a line bureau, the executive officers of these ships make formal reports, on a matter of which, personally, they know nothing.

The quotations made herein from the United States Navy Regulations prove fully their *ex parte* nature and show the unwisdom and the danger of committing to any one corps, even indirectly, the trust of formulating what are, in effect, the laws of that service.

VI. Discord Within the Line Branch.

The discord within the line of the navy has been noted previously herein. That body is divided into several factions which every Congress finds vigorously at war. The quarrel adds another, and a disastrous, element of weakness to the nation's naval force.

The question is purely one of promotion. The line of the navy is overcrowded; the seniors refuse to be retired; and the juniors see small hope of advancement. From 1861 to 1867, inclusive, there were entered at the naval school classes of extraordinary size. After the Civil War had ended, these officers, then supernumerary and youthful, were allowed unwisely to remain, and there is now a large number of them filling some of the upper grades of the navy. As they are all of about the same age, the natural result, shortly, will be that its highest grades will be monopolised by them until they are retired, practically, in a body. This list of officers forms what is known technically as the "hump," the excrescence on the fair curve of promotion,—that term having come from the able defense of it by one of its number who cited in argument the fabled quarrel between the camel and his hump, the moral of which was that the latter, though unlovely, was essential to the health and comfort of the camel.

And so, each Congress has its share of this discussion and its embryo legislation. The bitterness which has been aroused is shown, to some extent, by the quotations which follow from the printed argument of the "hump" bill against the latest "anti-hump" bill:—

"The attempt is to be made to select from about 260 officers, by classes, about 100 to be marked and reported as less competent and less worthy than the remaining officers. * * * The machinery devised for this part of the scheme, a secret and irresponsible board, a kind of star chamber, is a proof of the wrong contemplated.

* * * The operation of section 12 will keep the navy in a continuous state of commotion and strife. * * * The section is the parent of discord, the mother of suspicion and hate in the navy." (Argument by the Naval Association *in re* H. R. 790, 2915; S. 349; p. 6.)

"Scheme," "star chamber," "the wrong contemplated," "suspicion," "hate"—these are strange words to pass, in print, between officers who are to stand, shoulder to shoulder, in "the first line of defense" against a foreign foe.

VII. Conclusions.

In the *North American Review* for November, 1894, Captain Mahan has shown the importance of sea power to the United States. Referring to the two great English-speaking peoples, he says:—

"Partners, each, in the great commonwealth of nations, which share the blessings of European civilisation, they alone, though in varying degrees, are geographically so severed from all existing rivals, as to be exempt from the burden of great land armies; while, at the same time, they must depend upon the sea, in chief measure, for that intercourse with other members of the body upon which national well-being depends. * * * To other States, the land, with its privileges and its glories, is the chief source of national prosperity and distinction. To Great Britain and the United States, if they rightly estimate the part they may play in the great drama of human progress, is entrusted a maritime interest, in the broadest sense of the word, which demands, as one of the conditions of its exercise and its safety, the organised force adequate to control the general course of events at sea."

These eloquent words seem prophetic of the destiny of America, if she shall but take the tide at its flood; and yet, without speculation as to what may come, it seems apparent that the nation has, at this time, imperative need of a powerful naval force, with her leagues of defenseless coast line on the lakes and the two oceans; the prospect of trans-oceanic expansion which, with Hawaii, seems approaching, and the growth of her foreign commerce, whose sails begin again to whiten the seas.

The foundation of that force must be a strong and united personnel; and yet, from the facts set forth herein, it would seem that the United States navy is, in this, essentially weak, through the absence in its line corps of engineering training; through the dissension within that corps, and through the war waged by a portion of it against the corps of engineers. *The underlying causes of this strife are the changes which engineering has wrought in naval warfare and the fact that the corps which has controlled the navy from its formation, has not progressed to meet these changes, and has, during the period of the fleet's decay, retained excessive proportions, giving its officers scanty opportunity for sea service and abundant leisure on shore,*—leisure which, unfortunately for the nation, has fostered the growth of politics in this service and has resulted in the exercise, by officers, of undue influence on naval legislation.

It is a long step, indeed, from some of the political and non-seafaring sailors of this day to Commodore Decatur, dying, in his prime, on the "dark and bloody ground" of Bladensburgh, that, in the haughty, if mistaken, spirit of that time, he might protect his personal honour. It would be difficult to think of Farragut as issuing partisan circulars, or as using the prestige of his great name to push or crush a naval bill. These men fought, not in congressional committee rooms, but in the red carnage of battle or, out on the open ocean, with the Northern gale. To the thirty years of peace and politics which have passed since "the echo of the last gun, fired in earnest, died away," is due the discord and the inherent weakness of the naval personnel and the resultant dangers, which, despite its strong and stately ships, menace the nation now, in the event of naval war.

The strife between the line and the corps of engineers cannot be minimised or ignored. It is not a petty squabble,

as to points of discipline, which the country, in weariness, may leave for time to settle; but a warfare,—in some instances, vindictive, relentless, and unscrupulous,—between determined men, the result of which is, at this time, the practical crippling of the fleet.

"It is a revolt, then?" said the French monarch to his minister.

"No, Sire, it is a revolution," was the answer.

And so, the acute stage in which we find this struggle at this time is not due, as has been said, to the insubordinate spirit of discontented and ambitious engineer officers, but to a revolution in the methods and mechanism of naval war and in the training of those who shall conduct it.

An inspection of the Navy Register for January 1, 1896, shows, of the ships in commission, sixteen with one commissioned engineer officer only on board, five with two officers each, six with three officers each, ten with four officers each, and one armoured cruiser and one battleship with five of such officers to each. These figures include the chief engineers, who are not expected, except in severe emergency, to take a watch in the engine room. When there is borne in mind the severe strain on these officers, the tropic heat in which they toil, and the dangers, internal to the ship, which they must face, it is not reasonable to look for anything but collapse in the official engine room staff, during a prolonged action, in which ships, so under-officered, take part.

On some of these very ships we find the deck duty divided among four or five officers of the line, with naval cadets as occasional reliefs; while below, when under way, the chief engineer, an officer of rank and years, is compelled to take a watch to lighten the task of his juniors. The severe nature of that task is indicated in the report of the surgeon general of the United States navy for 1895. He says:—

"The average temperature of the engine rooms of modern ships, under ordinary cruising conditions, may range from 106 degrees F., with hatches large and open, like the *Charleston*, to 152 degrees in badly arranged and closed ships, like the *Amphitrite*.

"In the fire rooms the average temperature under the above conditions may range from 124 degrees in ships with only one set of fires in each fire room, like the *Charleston*, to 189 degrees, when the fire room is between two sets of fires, like the *Cincinnati* and *Amphitrite*. In the case of the *Cincinnati*, when only one set of fires is used in each fire room, the average temperature is reduced from 189 degrees to 159.

"The result of these high temperatures, together with overwork and other trying conditions, is plainly shown by the number of disabilities in the engineer corps attributed to this cause. Since January 1, 1894, eleven chief engineers and three passed assistant engineers (14 out of 173, or 8 per cent. of the corps) have been or are now on sick leave and of this number six have been recommended for retirement, and two have died."

It will be noted that these temperatures apply to "ordinary cruising conditions" when everything possible is done to reduce them. What will those of the *Cincinnati*, for instance, reach in action, with all fires going and the compartment doors closed? If her fire room is 189 degrees now, in the palmy days of peace, it will become an inferno then. And yet that ship with her two triple expansion engines and her 10,000 horse-power, has just three commissioned officers, one a chief engineer, who is not expected to take a watch when under way. Just here, a question seems not only pertinent, but necessary:—

At whose door lies the responsibility for the death or disability of the officers referred to in this report of the surgeon general of the navy?

It is important also, in this connection, to call attention again to the statement which has been quoted previously from one of the "arguments" of the Naval Association, to the effect that "there is no scarcity of naval engineers nor any probability of such scarcity." There have been given also herein quo-

tations from official documents which show that the secretary of the navy in 1891, the committee on naval affairs of the Senate in 1892, and the engineer-in-chief of the navy in 1893, stated in their reports that there were not then enough engineer officers. To these may be added the testimony of the chief of the bureau of navigation, a line officer of high rank, who said, in his annual report for 1890, that "the number of the engineer officers allowed by law is inadequate to the duties required of that corps." And yet the corps of engineers was larger in those years and the number of ships less.

In the face of such official statements and of the further facts given in the report of the surgeon general above noted, this association has had the folly and the temerity to print and circulate an assertion so misleading. It is said that the celebrated Francis Wayland once remarked, as to a man whose reliability he doubted, that "he would be a poor hand to write history." It seems that this association is also "a poor hand" in its self-appointed task of prescribing for the corps of engineers.

There is, however, another and more serious phase to this question. The statement is not only a direct contradiction of, and a public affront to, the official authorities who have been quoted, but it seems to be wholly at variance with the facts. If, then, the authorities referred to are not in error, the action of this association should meet, at least, the prompt and public condemnation of the navy department.

It is not pleasant to record or discuss such an incident in connection with an honoured service; and yet, it is essential in indicating the tactics by which the corps of engineers has been opposed and reduced.

The remedy for the troubles of the naval personnel can come only from without the service,—never from within; that has been tried for thirty years in vain. Admiral Colomb, of the British navy, says:—"The naval mind is unaccustomed to project itself onward. It is so practical that it will not move until it is pushed." And so, if the nation is to have an effective fleet, if its ships are built for use, Congress must apply the pressure which will bring a thought of the present and the future to the "naval mind" of this day; it must intervene to rearrange the force on a basis commensurate with modern needs, retiring officers known to be superfluous, especially those who have been prominent in influencing legislation, and filling the depleted ranks of those who bear the burden. With that rearrangement there should come also such legislation as will permit a revision, by an impartial commission, of the naval regulations, to the end that no one corps shall absorb hereafter the legislative, judicial, executive, and punitive powers of that service. Military discipline does not mean, necessarily, military despotism.

There is no warrant, historically or otherwise, for the arbitrary distinction in rank between the line of the United States navy and its engineers as a staff corps. The very designations of these branches are misleading. The so-called "line" is not, in a military sense, a real line; the so-called "corps" is never an actual corps, since it does not act as a body; and, if the term "staff" be used in the sense of auxiliary and inferior, it cannot, with truth, be applied to those engineer officers without whom there could be no naval battles, and of whom, in the British service, *The Engineer*, of London, says:—"The naval supremacy of Great Britain rests in the hands of the engineers."

The assertion is made, as to the engineer, that he is subordinate; that he is not a free agent. Quite true; but the subordination of all to the will and skill of one, is the basic principle of a ship's efficiency in a modern action. Is then, the engineer, in manipulating his machinery below the protective deck, in accordance with signals from the commander in his conning tower, more subordinate than the lieutenant in the turret, who receives, from the same commander and the same tower, the range, the elevation, and the order to fire his gun? The engineer manages a steam

engine of great complexity; the lieutenant manipulates a powder-engine of great simplicity; and both are subordinate to the man, who, holding in his grasp the nerves of the warship, bears alone the awful responsibility of command in battle.

Let us flash, briefly, the search-light of history on the so-called line and staff. The line of the United States navy to-day represents but the professions of navigation and gunnery. The seamanship of the old time, with its maze of masts and yards and sails and its wilderness of standing and running rigging, has vanished from the seas, and there is left but its faint shadow in the manœuvring of a mastless machine, which only steam can hold up to the north-west gale, and only steam can drive off a lee shore. In considering the navigator and the gunner, Commander Robinson, R. N., in *The British Fleet*, says:—

"The master and his mates were the sole navigating officers, and, up to quite the end of the great war, it was held no disgrace to an executive officer, providing he was a good sailor-man, to be neither navigator nor gunner."

That is to say, the United States line of to-day represents officers who, in the year of Waterloo, were auxiliary; and, if, in 1815, there had been a naval struggle for rank, the contest would have been waged against the "line" of that time by a "staff" whose main components would have been the gunners and the navigators. From the standpoint of history, then, these professions give no claim to superior rank.

The grade of "sailing master" existed for many years in the United States navy and the title, abbreviated to "master," remained until 1883. As to gunnery, Secretary Welles states, in his report for 1864, that "when gunnery became a specialty, it was inconsiderately and unwisely proposed to have a corps of ordnance officers engrafted upon the naval service." This corps, if it had been formed, would, doubtless, after the ancient custom, have been made a "staff" corps.

In discussing the vexed question of rank, much has been said as to the importance of the line officer as a strategist and a tactician. Let us measure the value of these claims! It is said that Napoleon, in derision, once remarked that "God was on the side of the big battalions." He did not think so at Marengo and on many another field; but such strategists as he, the Moltkes of the land or sea, are born, not trained. In tactics,—the handling of the fleet in line of battle,—the naval world has a subject, the difficulties of which can find solution only in wars upon the sea.

Since the last gun was fired in a great action, armour, ordnance, speed, the ships themselves, have been transformed; the ram has reappeared; mobile torpedoes, the torpedo boat, and torpedo catchers have been developed; and it seems probable that the submarine boat, as well, must be considered. These elements, many of them untried, make a combination which it would seem that genius alone could handle in the sudden fury of a modern action. No rules can mark its lightning changes; and, for its tactics, Napoleon's definition only will serve:—"The art of being the stronger," at the time of need.

Yet, assuming that there can be devised, in time of peace, a scheme of tactics which will have fair success in war, it may be said, that, in the brilliant victories of the past, tactics have been more honoured in the breach than the observance. Nelson, off Cape St. Vincent, made his manœuvre of masterly daring, not only in defiance of orders, but with total disregard of the tactics of that day. General Sir George Cathcart has shown, in his *Commentaries*, that Napoleon first dazed his opponents, by utterly neglecting the grand line movements of Frederick the Great, in which they put their trust; and then defeated them, in defiance of all they knew of tactics, by charging a weak point, in overwhelming force and under cover of a concentrated power of artillery.

We have noted the claims of some line officers upon this matter; we have seen the difficulties which the naval strategy and tactics of this day present.

If these problems do not admit of full solution, they, at least, deserve most careful study from officers who base claims to superior rank upon them. It is for labour that men claim reward. What, then, are the strategic labours of these officers of the line?

There is maintained at Newport a war college, the navy's only school of strategy. This school holds sessions during but four months of the year. At the session of 1895, there were twenty-five line officers as students. Of these twenty-five officers, eleven were detached before the end of the session, although that is "a detail." There are 715 officers in the commissioned line of the navy; assuming the yearly class to be twenty-five in number and that they all remain until the close of the session, it would take about twenty-eight years to give the line officers of the navy four months of instruction, each, in the great science of strategy and tactics.

In view of the intricate problems which the subject presents and of the utterly absurd attempt, as indicated above, to meet them, it may, with conservatism, be said that strategy and tactics, for the United States navy, exist as definitions only. An able officer of the line, practically, but perhaps unwittingly, admits this, when he says:—"Our books on tactics are primers; our signal books are a monument to those who do not go to sea; and the naval war college * * * is really about our only hope," etc. (Proceedings United States Naval Institute, Vol. 22, No. 1.) The delusive nature of this hope has been fully shown herein.

In reviewing the considerations on which a faction of the line bases its claims to a rank superior to that of the staff, we find these claims resting only on a seamanship which has vanished; on navigation and gunnery which, historically, are "staff" duties; and on strategy and tactics, of which these officers can know little. There seems need of stronger ground than this, to support that superiority in rank which a leader of this faction, in crude defiance of the English tongue, terms the "*hierarchy* of command." His warlike "priesthood" must present arguments more forceful than those, which, in all their naked feebleness, have been set forth herein.

The sea-fighter of the Roman age, with galley-slaves as his motive power, was a soldier, pure and simple; in Nelson's time he had become a sailor; in our day, when a battleship is but a mass of mechanism, he is, perforce, an engineer. Whether he fights within a conning tower, behind a turret's armoured walls, or beneath the battle hatches of an engine room, the high ideal, the isolation, the daring, and the sacrifice, must be the same to meet fitly the sudden horror, the wholesale carnage, of a modern action.

With such a similarity of training, of service, and of environment, there should be no distinction in rank between the line and the engineer officer. Let Congress, at least, do effectually what it endeavoured to do in 1871! Let it place the staff of the navy, as to actual rank and lineal title, on a level with that of the army, making the corps independent but giving the commanding officer supreme control of all, with the provision that he shall fulfill all the duties of his office and be without authority to delegate his powers!

Benjamin Harrison, ex-president of the United States, is reported to have said that one should not indicate a weakness in a national organisation without the suggestion, also, of a remedy therefor. In this paper, the endeavour has been made to point out the evils which are sapping the vitality of the naval personnel and which have crippled that arm of the national defence. The desire has been to do this fearlessly, but without bitterness and with full fidelity to truth. The writer has no personal wrongs from officers or corps to rankle in his memory and to add a needless sting to his words.

Since the remedy must come from legislation, it seems fitting that national attention be directed to the bills now pending in Congress which bear upon this question. It may be said that, of these measures, the most important, by

far, seems to be the engineering and educational bill (House of Representatives, No. 3618) introduced by Representative Francis H. Wilson, of New York. A careful examination of it reveals nothing that is not just, and much which is not only wise, but which seems essential to the national defence. It is not a cure, but seems a long step toward that end. The opinion which is ventured here seems but confirmed by the wide approval given this measure by engineering authorities and associations, and the universities and technological schools of the United States.

To the student of naval progress there appears but one logical outcome to this struggle. Times change, and men and methods must change with them. There has been in every age resistance to reform; there is always a reactionary party, and yet one would not look for it among the United States naval line, with its record of brilliant achievement in the past.

It seems strange, indeed, that there should be found within that body even a faction which, impelled by the fear that its historic prestige may be lessened and governed by the principle, "Cæsar or no one," would endeavour, with strange unwisdom, to reduce the numbers and impair the efficiency of those engineer officers through whom alone that prestige can be maintained in warfare.

Wrapped in the day-dream of a supremacy which is past, they do not hear the *fuit Ilium* of the old days and the old navy; they do not fear a coming day of wrath when—with, perhaps, a shattered engineer corps; with ships, which, without that corps, lie useless and idle; with, it may be, a lost battle, —an awakened nation shall require the reason for it all. In commenting on this attitude, the *Admiralty and Horse Guards Gazette*, of London, says:—

"The evolution of the naval engineer cannot be arrested; and, if the executive branch will persist in placing itself in a position of antagonism to the engineer, we fancy the great law of the survival of the fittest will settle the antagonism in due course."

Between this faction and the many line officers who are able, faithful, and honourable, fulfilling the best traditions of a gallant navy, the writer would draw a wide distinction. To his memories of service with these officers, of duty fitly done and danger nobly met, of hours of genial comradeship on distant seas, this acknowledgment is due.

ENGINEERING NOTES FROM JAPAN AND CHINA.

The First Twist Drills in a Chinese Machine Shop.

By F. F. Prentiss.

NAGASAKI, Japan, has one of the most picturesque harbours in the world. It is almost a circle, not more than three miles across and nearly enclosed by lofty mountains. The entrance is hardly one thousand feet wide, with modern forts and torpedo stations on either side making it apparently impregnable.

At this point is the largest ship building plant in Japan. Their rules for visitors are strict, and I was taken through on a run and not permitted to examine anything. With the exception of a few German lathes, the tools were English. The only American things I saw were Fairbanks scales.

The plant was very busy, having enough orders to keep six hundred men going for more than a year. Several additions were building; mortar, brick, and other materials were carried by girls and women.

Piles were being driven in one of the

new buildings, for a foundation for a punch. They were 8 inches in diameter and 14 feet long. The staging was bamboo and so was the frame for the hammer, which was a round piece of cast iron with a hole in the centre for a guide-rod.

Attached to the hammer block were twenty-seven ropes, carried up to the top of the frame and down on the outside, looking very much like the old-fashioned May-pole. Twenty-seven women had hold of the ends, and with a sing-song, all together, pulled down; up the rod, four feet, travelled the hammer; then, at a scream, all let go and down it came on top the pile which was unprotected by a band or ring. The women were paid 20 cents in gold per day. This May-pole pile driver is in general use throughout Japan and China.

Hong Kong is an island ceded to Great Britain in 1841. It is at the mouth of the Pearl river. It is the seat of government, picturesquely situated at the water's edge and extending back on the hills and, by terraces, up the sides of the mountains. It is the great centre of the foreign trade of China and a mart for opium, flour, ivory, cotton, sugar, salt, silks, tea and other products. It is the most important port in the East, and in 1894 vessels cleared with over ten million tonnage.

The wharves are lined with substantial stone warehouses. The mercantile firms are housed in fine stone or stucco buildings, looking like palaces, and the streets are narrow and choked with humanity from all quarters of the globe.

At one end of the city is a sugar refinery, which boasts of being the second largest in the world. This, with the government arsenal and repair shop, were the only factories I found, excepting, across the harbour, the Dock Company, which is a mammoth institution and would be a credit to the Clyde or Delaware river. It was started many years ago by an American, named Ward I believe, and is to-day as well equipped for repair work as any plant in the world.

They have six stone dry docks, the largest taking vessels 540 feet long, and another is building, with a capacity of 650 feet and will cost over $1,000,000 gold. Beside these facilities for handling work, there are two slips with massive cars on tracks running into the water 700 feet. Moderate sized vessels can be pulled out high and dry in two hours.

Competent draughtsmen, foundry, steam-hammer shop, machine shop with electric cranes, telephone stations and tools of modern, up-to-date make enable this shop to turn out the best work in the East. There was an air of system and bustle about the plant that was a credit to the management and I was not surprised to learn later on that the company has just declared a semi-annual cash dividend of 8 per cent. The fortunate stockholders are Englishmen.

Foo Choo, some five hundred miles up the coast, is decidedly a Chinese city. It is surrounded by an amphitheatre of hills and part of it is enclosed by a high stone wall, ten miles around. The Min river divides the city and is crossed by a stone bridge, said to be one thousand years old.

This place is noted for the manufacturers of cotton goods, porcelain, blue lacquer, and as being the centre of the black tea industry. Near by are some extensive lead mines.

The tea business seemed to be in the hands of the Russians. They have here two large factories for making tea cakes. The tea is ground fine, almost to a powder, and, then, by powerful hydraulic presses, is forced into blocks 9″x7″x1″ thick, that are so hard that it is impossible to break them without a blow with a hammer. These are sent north through the great Chinese Wall into Mongolia and Siberia, and pass current as money. In many localities it is the only currency used.

As the blocks leave Foo Choo they weigh the same to an ounce, and the fortunate merchants do not have the vexed American money question of 16 to 1 to disturb their dreams. As the money circulates around, however, pieces are chopped off to replenish the tea pots and the blocks depreciate in

value in proportion to the chunks taken off.

At Kucheng, a few miles up the river, the frightful massacre of missionaries took place in August, last year. The natives were still in an ugly mood and foreigners were cautioned not to go about alone, and it was, consequently, with considerable trepidation that I engaged a steam launch and interpreter to take me down the river twelve miles to the naval arsenal.

The appointment was for 8.30 the next morning. I was on the wharf at that hour, but nothing was in sight excepting hundreds of sampans (Chinese river boats), and junks. I walked up and down calling Ah Kum (the name of the interpreter engaged, whom I had not seen). A crowd of at least fifty natives followed me back and forth, enjoying my dilemma, and, I have no doubt, wondering if I had gone out of my head.

I happen to be the owner of a pair of blue eyes. Now it appears that they are a rarity in China and possess the marvellous power of penetrating the very soul of a Chinaman and reading his secret thoughts. It amused me a good deal, as I glared at the boys on the inside of the circle that surrounded me, to see them shrink back and work out of the crowd in a hurry, turning to see if I followed up the attack.

Half an hour passed, and during that time a number of sampans and junks worked out of the way, showing a small American flag in the stern of a launch. That must be the craft, so with a lot of gesticulations, I succeeded in getting it to the wharf; but no Ah Kum.

The Chinaman at the wheel and his crew of two natives had a consultation and after a long and emphatic sign dispute we started down the river. Evidently they had been told where to go, for we dropped anchor opposite the arsenal without a mishap and a sampan took me ashore.

A high stone wall faced me and over the top I could see a number of brick buildings and stacks. This evidently was the place. But how should I get in? A crowd surrounded me immediately. Selecting a bright-looking chap, I gave him a coin and handed him my sample case of twist drills, at the same

CHINESE PIG IRON. THE PIGS ARE LONG AND THIN, QUITE UNLIKE IN SHAPE FROM THOSE MADE IN ENGLAND AND AMERICA.

time pointing over the wall. He started down the street, I following at his heels, and the crowd back of me.

We went into several houses, why, I cannot say. In one of them my samples were transferred to an old man and I and the crowd followed him through several streets and up a long flight of stone steps to a large stone building with soldiers stationed at the entrance.

This must be the office; so I handed out a card that was taken inside. There was a long wait and then the bearer returned, shaking his head and pointing to my launch. I showed I was deeply disappointed; then, taking out two drills, sent them in and immediately was invited to enter. The official was polite, bowing and shaking his own hands, as is the custom among Chinamen, and offered me a cup of tea.

There happened to be several forgings in the room and as I pressed the drills against them and pointed to over the wall, he seemed to comprehend what was wanted, and in a few minutes I was in a large well-lighted machine shop. I might say this extensive plant was built and equipped by French engineers some fifteen years ago.

The native foreman examined my tools with great interest and called in several assistants. All looked puzzled and did not seem to know what they were for. Walking to a drill press, I took out the flat drill and after considerable packing around the shank, succeeded in getting one of my taper shank twist drills to run fairly true in the spindle. There must have been fifty Chinamen working in the room and every one had gathered around this press. The foreman ordered them off repeatedly, and then, looking at me, laughed good naturedly and gave it up.

He brought a piece of cast iron, but I wanted something harder to drill, so I walked over to a large planer and took a long extension tool, made from 3″x1¾″ tool steel, and clamped it to the table of the drill press. He shook his head, intimating that the twist drill could not go through, and the crowd of workmen emitted grunts of approval.

The press started, the lips of the twist drill turned out two spiral chips; the men elbowed me to one side; there was a sea of pig tails bending down, watching the marvellous action of that little tool. As the chips grew in length the expressions of wonderment increased.

It happened that the chips did not break until they were about 14 inches long; then others started, and each time that they broke off, they were eagerly snatched by the men, some burning their fingers, and examined carefully from end to end.

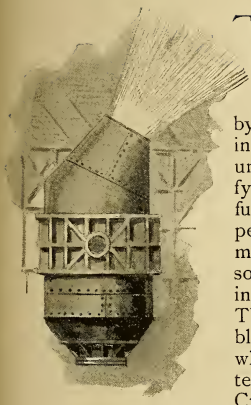
The dull edges of the drill were shown around, and then ground and started again, and the fact that the drill would cut as well as the first time caused increased amazement and murmurs. I have made many tests with twist drills, but never before such an appreciative and demonstrative audience.

SIR HENRY BESSEMER.

A Biographical Sketch.

By Dr. R. H. Thurston.

(*Concluded from page 337.*)



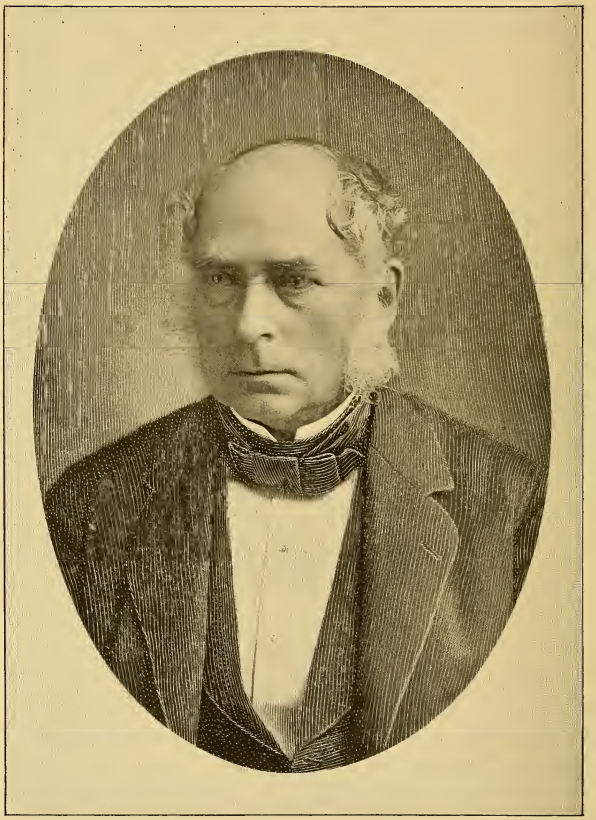
THE exhibition of Bessemer steel at the Paris International Exposition of 1867, by licensees of the inventor, brought triumphs no less gratifying. Bessemer refused to exhibit, and permitted the new metal to be shown solely by his licensees in that country. They received suitable and high awards, while Bessemer was tendered the Grand Cross of the Legion of Honour by the Emperor of France, and the report of the imperial commissioners, made notwithstanding the fact that he was not an exhibitor, asserted that "the most remarkable victory gained by metallurgy in the previous ten years" was due to Bessemer, who had "enriched the industrial world with a new metal."

The British government, which seems to have been exceedingly unjust and unkind to its greatest modern benefactor, throughout these years of trial and struggle, refused him permission to accept the Grand Cross and thus added further mortification to the not infrequent injuries already done him, while perfecting his steel, in its suppression at Woolwich and by other neglects and slights. But, from this time on, the process made its way with great rapidity into all the civilised countries of the world. Bessemer's victory was now complete.

The Bessemer process, or the pneumatic process of steel making, is substantially the same to-day as then, in all its essential details, although the genius of Bessemer in Great Britain, and of Holley and others in the United States, has so perfected its details that the production from a single converter and from a "plant" has been enormously increased by making it possible to keep the converters constantly at work, day and night, almost without limit. This process is one of the most impressive as well as most remarkable known in the arts.

In detail it is as follows:—Molten cast iron is poured into a vessel of egg-shape, in which it is exposed to the blast of air at high pressure, driven through the fluid mass in fine streams from below, permeating it throughout and constantly with threads of air and their burden of oxygen, and thus burning out the carbon and the silicon which constitute the main difference, so far as regards chemical composition, between the iron and the steel into which it is to be transformed. The heat produced by this combustion is sufficient to keep the mass molten, and no fuel is required after the process has once been initiated in the converter.

The spectator, visiting a Bessemer works for the first time, is very greatly impressed by the magnitude and brilliancy of the operations involved in the conversion of the molten cast iron into steel. The cast iron is sometimes brought direct from the blast furnace to



Very Sincerely yours
Henry Bessemer.

FROM A PHOTOGRAPH TAKEN IN 1884 AGE 71.

the great vessel in which it is changed into the more useful metal, in some cases even being transported a distance of one or two miles in the liquid state; sometimes it is melted in "cupola" furnaces, located near the converting vessel, but in all cases, a rich dark, siliceous cast iron of peculiar composition, "Bessemer No. 1" usually, is melted, and poured, in a perfectly fluid condition and at a dazzling white heat, into the converter. This converter is an egg-shaped vessel, mounted on trunnions, so arranged that it may be tilted in either direction, toward the source from which is received the iron, or in the opposite direction toward the ingot-moulds.

The converter being turned back and so inclined as to most conveniently receive its charge, the stream of molten, glowing, scintillating iron flows down a trough of iron, lined with refractory clay, into its mouth, with a noise like the rustling of leaves in a gale, lighting up the whole dark interior of the cavernous "converting house" with its glare of white light, hardly less brilliant than that of the electric arc. From five to ten tons, according to the size of the "plant," being thus transferred to the converter, the latter is turned, by hydraulic and invisible mechanism, directed by the hand of a boy on a distant platform, into the vertical position, its mouth, or "nozzle," being thus brought directly opposite an opening into a chimney flue, located there for the purpose of carrying away all smoke, fumes and sparks of burning carbon or iron.

As this operation proceeds, the blast from great blowing engines, forcing enormous volumes of air under high pressure, is turned into the "blast box" in the bottom of the vessel and, as it rises into the vertical line, this air, penetrating the liquid iron in fine streams, and pervading its mass in every part, searches out the molecules of silicon, first of all, tears them from their companion molecules of metal and oxidises them. The resulting compound, silica, so much liquid sand, is floated to the top of the pool of fluid metal, covering it with a protecting cushion which preserves it from loss of heat and from the influence of the atmosphere, while smoke and sparks and flame, driven before the blast, pass in a roaring and reverberating, blazing and corruscating, thunderstorm up the flue into the outer atmosphere, lighting the surrounding country as with a gigantic torch.

As the volcanic display continues, the whole great mass, trembling on its foundations with the violence of the blast and the impulses of the concussions of the contending atoms, the white flame thus purified and taking a tint of sapphire as the operation proceeds, denotes the combustion of the silica, taking on somewhat suddenly a duller and brownish hue, the sparks cease to scintillate in its midst, and the combustion of carbon is begun, all silicon, the first affinity of the oxygen, being entirely exhausted.

The carbon has now begun to disappear, and the first step in this part of the operation is the combustion of that which is graphitic, and not chemically combined with the iron. The threatening and continually quivering tongue of fire issuing from the converter's mouth, now obscured by smoke, after a little time once more becomes clear, and the burning out of the combined carbon has commenced; the oxygen seizing upon that which is held in the embrace of the ferrous molecules, and, taking them away from their combinations, uniting with them, forms carbonic acid gas.

After a few minutes more, perhaps fifteen or eighteen minutes from the commencement, the flame begins to flicker, sparks of burning iron suddenly begin to appear, and the process has reached its limit; the converter is turned down, the blast is shut off, and the molten iron, purified of all its former contaminating ingredients, and containing only a little oxide and entangled air, receives a weighed dose of melted manganese, combined with carbon and iron, to give the metal soundness by absorption from it of any existing oxygen, that may, if left, produce "blowholes" in the finished steel, and also to insure that the right amount of carbon to give

the desired quality and temper of steel is introduced.

The charge is then poured forth into the heated ingot-moulds, arranged in a circle about the edges of the converter pit. It issues as a stream of light, the metal being even more highly heated than when it entered the converter; for the whole process of conversion has been one of production of heat, and, despite the immense amount of caloric carried away by the air and gases passing up the chimney, the temperature required to keep steel above the melting point, —a temperature higher, much higher, than that of molten cast iron,—is produced and maintained.

The whole process is one demanding, as a primary requisite, that the molecules and the atoms in combination, or possessing affinities for each other, shall be held so far apart as to permit the transformations, the compositions and the recompositions, of the operation to proceed, and this can only be done by the action of heat-energy of a certain intensity. The province, therefore, of heat, in this case, is to apply power to that adjustment of relative positions of molecules and of atoms which no other

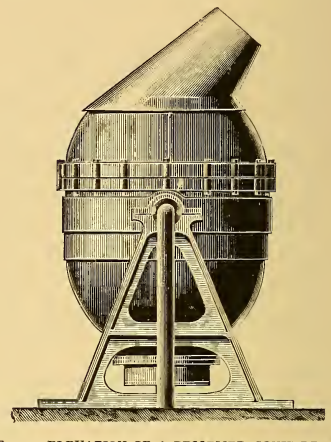


FIG. 1. ELEVATION OF A BESSEMER CONVERTER.

quantity, we should be able to trace the action of those laws at each step. Every detail of the process in which a

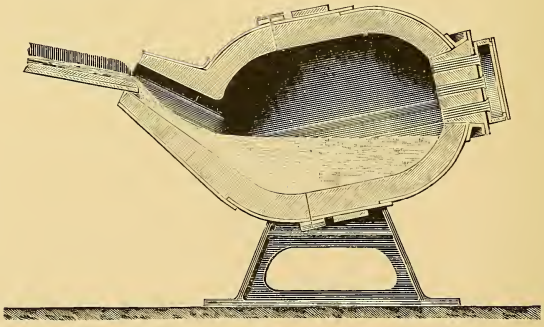


FIG. 2. POSITION OF A CONVERTER WHEN METAL IS POURED IN.

known energy can give, and thus to assist the engineer and the metallurgist to attain results probably otherwise entirely beyond his reach.

Transformations of heat-energy take place here according to the established laws of thermodynamics, precisely as elsewhere, and could we penetrate the converter, and apply our means of measurement of temperature and heat-

composition or a compound, of whatever chemical nature, is, in the course of that operation, torn into its constituent elements, demands a definite and known quantity of converted energy to do the work; every case in which two

or more elements enter into new combinations, whatever their extent or the character of the product, is a case of development of heat by the conversion into that form of energy of the potential

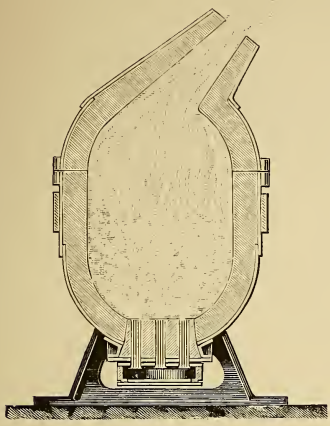


FIG. 3. A CONVERTER IN BLAST.

energies, before latent, in the relations of attractions and distance of the combining particles.

This beautiful and impressive process is that which, to-day, supplies the world with a material for use in construction which may be given either tenacity and hardness, the temper and elasticity of tool-steel, or the combined ductility and strength, the "resilience," of the softer steels, or the softness, ductility and malleability of the finest Swedish iron.

In the series of illustrations on pages 438 to 440, taken from the inventor's descriptive monograph, Fig. 1 is an elevation of the converter, showing the rings of bolts by which its two parts are held together when in use, being separated when the converter requires new lining. Fig. 2 shows the position assumed by the converter when the metal is poured in, the tuyeres being elevated above the line of the inflowing metal. Fig. 3 shows the converter in full activity with vertical streams of air passing upward under a pressure of 18 or 20 pounds per square inch, producing a fiery ebullition by the action of the forty-nine separate streams of air thus driven through it. Fig. 4 shows the converter tilted over, and the converted metal pouring into the casting ladle, the tuyeres being here, also, above the line of the molten steel and the air shut off.

Figs. 4 and 5 exhibit the "valvular ladle" by means of which many moulds may be filled in succession, and all slag prevented from entering with the flowing steel. As the inventor writes, "molten steel, with slag floating on its surface, could not be poured from the spout of a common ladle without mixture of metal and slag taking place. It must also be observed that pouring from the lip of a ladle gives a stream which would strike against one side of the mould in its descent, and this would be fatal, as the falling stream would melt the cast iron mould at the point of contact, and the ingot and the mould would be hopelessly ruined." Fig. 6 shows the construction of the bottom of the converter, its air-ducts, and the fire-brick removable plugs in which the ducts are made.

The engravings on pages 441, 442 and 443, reproduced from photographs, were sent to the writer by the inventor, at the request of the former, and illustrate some of the earlier work of the Bessemer process.

"In the years 1859-60," as Sir Henry

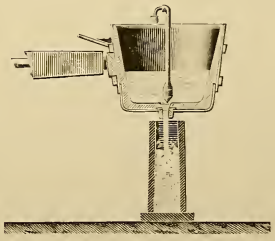


FIG. 4. THE VALVULAR LADLE.

says, "Messrs. Bessemer & Co., of Sheffield, manufactured a great many field guns of Bessemer steel. These guns were generally 18, 24 and 32-

pounders, forged solid from ingots of cast steel, and, in order to be certain of the quality of the steel, every gun had a portion of the metal of which it was composed forged down at each end into a 'tail-piece' (Figs. 7 and 8).

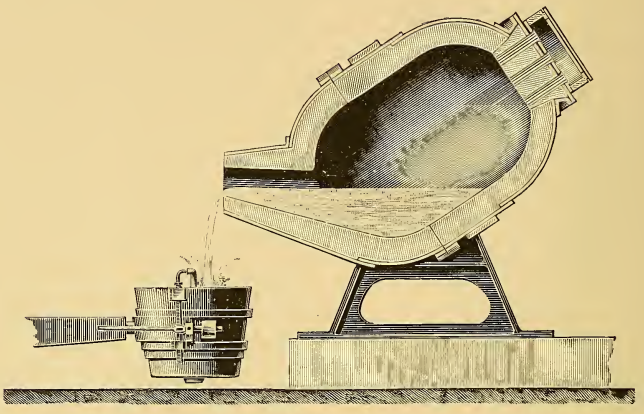


FIG. 5. POURING FROM A CONVERTER.

These projecting pieces were invariably made 3 inches by 2 inches in cross-section, and about 15 or 18 inches long. The projecting piece was nicked and broken off cold to show the fracture, and then bent double under a steam hammer when quite cold. This violent treatment produced no cracks or tearing of the sharp angles, as will be seen on inspection of the photographs."

The next illustration, Fig. 9, as the same authority states, "shows how violently Bessemer mild steel may be treated at a proper working heat. This specimen is one-half of a steel bar, 3¾ inches square. It was heated to a fair forging temperature and was held fast at one end, while the other end was attached to the main shaft of a steam engine and twisted until it gave way in the centre. Toward the extreme end, the corners of the bar that were originally 3¾ inches apart have approached, in the coil, to ¼ or ⅜-inch."

It is this process which has practically supplanted iron for all constructive purposes, as well as for most kinds of mechanisms. Great Britain and the United States now produce, annually, very nearly ten millions of tons of pig-iron. Of this, 50 per cent. in the United States, and a somewhat smaller proportion in Great Britain, passes through the converter and finds its way into the markets of the country and of the world as Bessemer steel. The prediction of the inventor has come to be true and the "age of steel" has come; the "age of iron" is passed forever.

Owing to the defective and inequitable forms of patent-law, adopted by the continental nations of Europe, Bessemer never secured either fair or con-

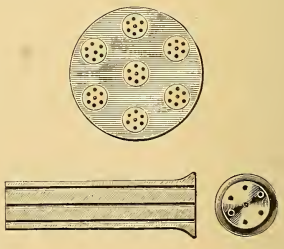


FIG. 6. CONVERTER BOTTOM DETAILS.

FIG. 7. A TEST PIECE FROM A BESSEMER STEEL GUN.

siderate treatment from the numerous iron and steel makers there taking up his process with great profit to themselves and advantage to their respective countries; but, by 1866, there were seventeen Bessemer steel-works in Great Britain paying him moderate royalties and, in the case of the Barrow Company, making a thousand or twelve hundred tons of steel a week, with extensions in progress sufficient to double that output.

Steel rail making had already begun, and, in the sessions of the Birmingham meeting of the British Association for the Advancement of Science, Bessemer had been able to show the results of an experiment in which, at a hard-worked point in a line of railroad, he had laid down a length of some considerable extent of steel rails on one side and of iron rails of equal weight opposite them, in such manner that every passing train would affect the iron and steel as nearly equally as possible. The outcome was the removal of twenty-three iron rails while the steel rails remained serviceable. With a relative endurance of

twenty-three to one in favour of steel, iron rails were doomed. They are to-day unknown in the market and have not been made for many years.

The London and Northwestern Railway Company introduced this steel into their boilers in 1863, and locomotive boilers are to-day built almost universally of mild steel. Adamson had, as early as 1860, experimentally employed it for stationary boilers. In 1863, Bessemer plate was employed for the first time in shipbuilding, and all ships are to-day built of this, then novel, material. By 1864, ordnance and projectiles in considerable numbers had been produced,—but for foreign governments only. Two years later, the process was bringing its inventor an income from all sources of about £500,000 annually.

Meantime, the busy brain of the inventor was continually seeking new ways of benefitting mankind. He devised the system of compression of the fluid and solidifying ingot, to insure soundness, — a system now famous through

FIG. 8. ANOTHER VIEW OF THE TEST PIECE ON PAGE 441.

the later work of Sir Joseph Whitworth; he invented a high-pressure furnace in which gases, combining under great pressure, developed an intensity of heat till then unknown in the arts of metallurgy. A method of direct production of steel from the ore was the subject of thought, and labour, and of prolonged experiment. Sir William Siemens ultimately attained some success in the same direction.

Bessemer devised a system of reduction of sponginess and of prevention of "blowholes" in steel by a mechanical stirring of the bath before pouring into the ingot-mould, and he may thus claim the credit of the invention of the most successful processes, looking to this end, now known. He invented a method of suspension of a ship's cabin on a set of "gymbals" with the purpose of evading seasickness, and actually built a steamer which was tried on the Dover and Calais crossing of the British channel. He brought out a new lathe for cutting and grinding lenses, and became a rival of Herschel and Lord Rosse in the construction of powerful telescopes. No department of science or of mechanics was unknown or uninteresting to him, and in none did he fail to see opportunity for invention and improvement.

By 1880 Sir Henry Bessemer had taken out a hundred and twenty patents, and had, it was estimated, paid into the British Patent Office about £10,000. The drawings were all made by his own hand, and the specifications and drawings, together, fill nine large volumes. The only improvement of the Bessermer pneumatic process in any manner, which has come into successful use through the labours of another mind, is the so-called "basic process," in which a lining of material rich in lime or other "basic" or alkaline substance, is employed for the purpose of eliminating phosphorus; thus permitting the use of ores otherwise not adaptable to the older pneumatic system of steel making.

This, which is a process patented by Messrs. Gilchrist and Thomas, now produces a large amount of steel of fine

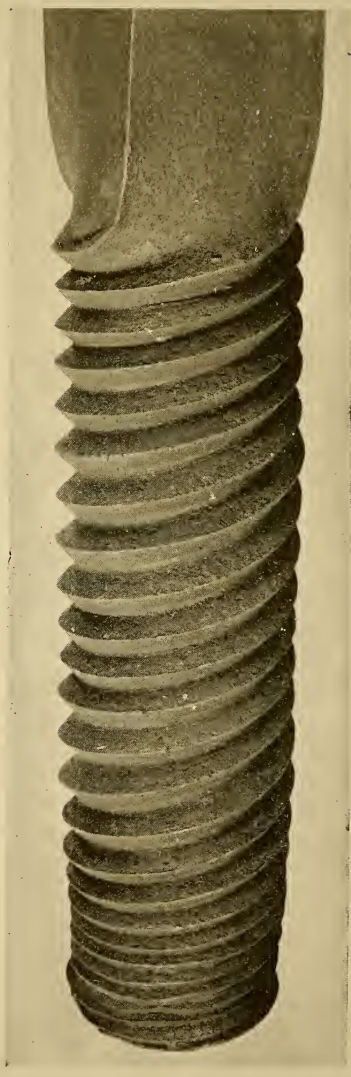


FIG. 9. EFFECT OF TWISTING A BESSEMER STEEL BAR.

quality from ores comparatively inexpensive, and which are otherwise incapable of employment for any purpose demanding freedom from the deleterious action of phosphorus. The softest steels made by this method are particularly useful for purposes, such as wire-drawing and wire-nail making, which demand exceptional ductility. The machinery employed in the Bessemer process is the invention, primarily, of Bessemer himself, but innumerable improvements, in details, have been effected, on both sides the Atlantic, by engineers working this method.

The modern Bessemer steel-works are hardly less remarkable for their wonderful adaptations of steam-power to all the principal operations, and the extraordinary labour-assisting devices that characterise them, than for the beauty and simplicity of all primary operations. The Bessemer process was promptly taken up in the United States, largely through the energy and skill and intelligent foresight of Alexander L. Holley. It was made extraordinarily productive by the combination of great capital with high engineering skill, and ultimately became a source of profit to all concerned, although it was not until after the expiration of the earlier patents and during the short period of their extensions and of perfection of details of the machinery of the works, that these profits came to be sufficient to remunerate any one. In the United States to-day are produced annually about five millions of tons of this steel, and more than is produced by any other two nations, probably more than all other nations together.

According to Smiles, in the twenty-one years succeeding the introduction of this new metal, not less than 21,000,000 tons were made, at a valuation of about $5,000,000,000 (£1,000,000,000). There are probably to-day about two hundred establishments employed in the work of production, and perhaps 6000 converters. In 1870, the original patents having expired, the profits of the inventor were stated at about $5,000,000 (£1,000,000). The Sheffield works paid their proprietors eighty-one times the originally paid-in capital in fourteen years. Meantime, the work of the world is done with Bessemer steel, and puddled iron has been largely relegated to the limbo of the by-gone.

The maximum production of iron and steel, including Bessemer metal, in the United States, has been reached in the year 1895, and amounted to about 9,500,000 tons,—the largest product of any nation in the world. Sir Henry Bessemer takes the world's product of this steel in 1892, at 10,500,000, and, assuming that 40 per cent. of this amount was converted into rails, its value is reckoned as eighty-four millions sterling, or pretty nearly $420,000,000. Upon these statistics are based some of those striking and helpful comparisons for which he has always been noted; for he combines the power of scientific use of the imagination with ability to provide opportunity for that talent in a most exceptional manner. He says*:—

"Let us use the mind's eye to assist us, and imagine standing erect before us a plain round column or tower of solid steel 20 feet in diameter and 100 feet high; this, no doubt, would impress us as a very large and heavy mass, and but few persons would be prepared at first to accept the simple fact that the production of Bessemer steel in 1892 would make 1671 such columns and leave a remainder of 5535 tons. Yet such is the fact. These tall columns would form a goodly row, and, if placed side by side in a straight line, and in contact with each other, would extend to a distance of 6 miles and 580 yards; indeed, there is on an average 5⅓ such columns produced on every working day in the year, bringing up each day's production of steel to 33,546 tons, as compared with Sheffield's former production of 51,000 tons annually.

"We may put this in another way, and imagine a plain cylindrical solid column of 100 feet in diameter, a good idea of which may be formed by a glance at some of the very large gasometers in the metropolis; then further imagine this gasometer, not as a thin

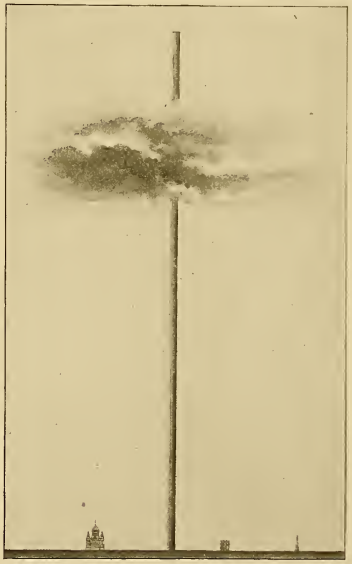
* *Engineering Review*; July 20, 1894.

iron shell, but as a ponderous solid mass rising before you to an altitude of 6684 feet 6 inches, or nearly one mile and a third in height. Such a huge solid mass would be exactly equal to one year's make of Bessemer steel. But even in this form we must draw powerfully on the imagination; for but few persons can in their mind's eye fully realise a huge solid mass of such heavy matter rising to more than sixteen and a half times the height of the cross of St. Paul's."

A graphic representation of such a column of steel standing between St. Paul's cathedral and the monument erected to commemorate the great fire of London, is shown on this page.

"It must be remembered that the process of converting crude iron into steel goes on ceaselessly in the converter for the whole twenty-four hours of each day, so that one hour's production is only one twenty-fourth part of a single day's work; but if all the steel produced in the Bessemer converter in this short interval of time were collected, it would form a solid cylindrical mass of 8 feet in diameter, and 139 feet in height, thus overtopping the Duke of York's column and the Nelson monument. What a noble portico would twenty-four such columns make, the work of a single day, but yet large enough to dwarf the grand old ruins of Karnac or Thebes.

"It may be interesting to put this matter in another form, in order to bring it vividly home to the imagination. A steel ingot of one ton weight is as nearly as possible five cubic feet of solid matter. Let us now imagine a solid square ingot of steel, having a base measuring 50 feet by 50 feet, and standing, say, 400 feet high. This would make a square tower of solid steel much larger than the clock tower of the Houses of Parliament, which is precisely 40 feet square, and about half as high as this imaginary square tower; in fact, such a tower would only be about four feet below the top of the cross of St. Paul's cathedral. This tower would contain precisely 1,000,000 cubic feet, and would weigh just 200,000 tons. Now, the Thames embankment from Westminster bridge to Blackfriars bridge, measured down the centre of the roadway, is one mile and a quarter and a few yards. Let us suppose one of these gigantic towers to stand opposite the clock tower, and in a line with the roadway over Westminster bridge, and a similar one erected at the other end of the embankment in a line with the roadway passing over Blackfriars bridge. Let us further imagine fifty other precisely similar towers



SOLID STEEL COLUMN, 6684 FEET 6 INCHES HIGH AND 100 FEET IN DIAMETER.

Representing the world's production of Bessemer steel in 1892. St. Paul's Cathedral, London, is shown at the left and the Monument to the fire of London at the right.

placed equi-distant between them, thus leaving a space of only 27 yards between each tower. This row of gigantic towers would represent 10,400,000 tons, or just 100,000 tons less than one year's production of Bessemer steel, each of the fifty-two towers being 1,923 tons less than the average weekly production.

"We might think of many other object lessons that would be likely to convey to the mind's eye a vivid and realistic picture of the enormous bulk of matter represented by 10,500,000 tons of steel. Let us select one other illustration. Imagine a straight wall 100 miles in length,* 5 feet in thickness, and 20 feet in height. Such a wall would stand on 60½ acres of land. But suppose that this wall, like a gigantic armour-plate, was formed into a circle, and used to surround London; the enclosure so made would extend to Watford on the north side, to Croydon on the south, to Woolwich on the east, and to Richmond on the west. It would, in point of fact, form a circular enclosure of 31¾ miles in diameter, and would embrace an area of 795 square miles. This great wall of London would just be equal to a single year's production of Bessemer steel.

"The great financier who is constantly dealing with the realised values of many millions would have a very keen appreciation of what £84,000,000 really means, yet I doubt if even the chancellor of the exchequer could offhand give anything like the correct dimensions of a mass of standard gold of that value. It can, however, be easily ascertained with accuracy. Since fifty-seven sovereigns weigh just one pound avoirdupois, the weight of 84,000,000 sovereigns would be 657 tons 17 cwt. 3 qrs. and 16 lbs., and as the specific gravity of standard gold coin is 17.167, we should have a mass equal to 1374.70 cubic feet, from which we could make a plain cylindrical column of solid gold 5 feet in diameter and 109 feet 5 inches in height, as a representative of the commercial value of the larger column of steel which I have referred to. It is an interesting fact that the statistics published by the *Annales des Mines* for 1893† show that it would take more than three years' production of all the gold mines in the world to pay in gold for one year's production of Bessemer steel."

* Or more accurately 99 miles and 2,280 feet in length.

† Taken from a paragraph in the *Times*, showing the weight in tons and value in pounds sterling of the world's production of gold in 1893.

The value of the service of this great inventor to the world, in the introduction of this invention, is to-day difficult to estimate. But we are now producing, annually, about $200,000,000 (£40,000,000) in gold from the mines of the world. The United States would to-day be producing, were they not in the midst of one of their often recurring and always unjustifiable business flurries, not less than 5,000,000 tons of Bessemer steel, and there would be as much more in other countries,—a total of ten millions of tons. Taking the gain thus accruing to the world as averaging only $20 (£4) a ton, the profits of the Bessemer process are now $200,000,000 (£40,000,000) a year, and equal to the full value of the world's gold production for the same period. It would require, in other words, all the gold of the world to pay, in coin, the mere profits of our use of the Bessemer process, and very much more would be needed to pay the market value of this inconceivable output.

When it is remembered that this metal was marketed in its earlier days at several times its present prices, and even then competed successfully with rival materials, it is obvious that, while it is difficult to compute with any degree of accuracy the profits made by the world in this case, it is very probable that they amount to more than the sum of the gold and silver production of the whole world, and that the indirect benefit to the world by stimulation of trade and manufactures, by supplying work for an increasing population, and by affording advantage in safety, comfort of living, and increasing ease, and progress throughout the world, is far beyond estimation. Of our computed profits, as above stated, the inventor has received perhaps a paltry 2 per cent., and, among inventors, he is most extraordinarily fortunate. The world is not kind to inventors, as a rule.

Thus, the inventor of the pneumatic process of steel-making has not been entirely unrecognised or unrewarded. His fate has been vastly more enviable than that of most of his confreres in this department of philanthropy. A hand-

some fortune is the pecuniary payment of the world for his many times greater contribution to its wealth. He was elected president of the Iron and Steel Institute of Great Britain in 1871, and was made a member of the Institute of Civil Engineers in 1877, and a fellow of the Royal Society of Great Britain in 1879. The same year he was knighted by the Queen, at Windsor, and in the next year he was presented with the "freedom of the city" by the governing authorities of London, "in recognition of the valuable discoveries which have so largely benefited the iron industries of the country, and those scientific attainments which are so well known and appreciated throughout the world."

In foreign lands, also, Bessemer received merited honour. The King of Wurtemburg presented him with a gold medal and a letter of acknowledgment of his great services to the world. The Emperor of Austria conferred upon him the honour, Knight Commander of the Order of Francis Joseph, with a letter conveying to him in suitable words of compliment its circular collar and jewelled cross. The Emperor of the French sought to do him similar honour in conferring the Grand Cross of the Legion of Honour; but this was denied him by his own government. The Emperor, not to be quite defeated, at the succeeding exposition, presented him with a great gold medal weighing twelve ounces. The Society of Arts and Manufactures of Berlin, presented a gold medal and honorary membership.

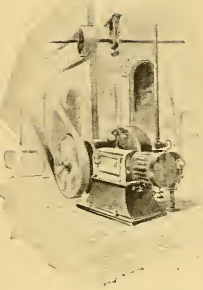
Honours now began to come to him at home more freely, and the Prince of Wales presented him, in 1872, the Prince Albert gold medal, as to a worthy successor of its earlier recipients, Rowland Hill, the Emperor Napoleon, Faraday, Wheatstone, Whitworth, Liebig, de Lesseps and Cole; and then came the other medals already mentioned. But, of all the compliments tendered him, one of the most genuine, and perhaps the most appreciated, came from America, where citizens of the United States founded a town in the centre of what was coming to be one of the greatest iron mining and manufacturing districts of the country, and called it Bessemer, and a number of places in various States have since similarly paid him honour.

Personally, Sir Henry Bessemer is one of the most striking and interesting of figures, and intellectually one of the most impressive of even the great men among whom he is a leader. His face is dark, his features marked and strong, his eyes clear, dark, expressive and penetrating, his figure is compact and powerful, his manner dignified and yet attractive and magnetic. He speaks and writes easily and clearly, with excellent choice of language, a fine rhetoric, and an ample vocabulary.

Among strangers he is somewhat reserved, among friends always gracious, sympathetic and social. His face would attract attention anywhere, and in any company his manner would impress any observer and his conversation would please the most intellectual and learned. In private, in public, and in his position of perhaps the most famous, and deservedly so, of living inventors, he is alike notable and admirable.

ENERGY TRANSMITTED BY COMPRESSED AIR.

By Charles A. Hague.



A FEW years ago it fell to the lot of the writer to examine and apply indicators to the various steam pumps and engines, operated by means of compressed air, in and about two large iron mines, and as the subject of the application of compressed air is now seemingly rapidly coming to the front as a practical question in the conveyance of power from generating sources to points of use, it might be of some little interest to note the results obtained on that occasion.

The pressure employed at these mines was 60 pounds per square inch, obtained at a single compression, compounding not having yet assumed practical shape, although beginning to attract attention. The installation of the plant had been brought about by the presence of a very liberal water power, and the absence of fuel at a reasonable cost. Its success and economy justified the courage and enterprise of its projectors, owners, and builders. The compression of air, its transmission and employment, under the conditions found in this case, and at the pressures reached, would very likely not be profitable if the work of compression were done by steam engines of however high a grade and type, and the air under pressure utilised for driving street cars.

It now remains to be ascertained whether or not the pressures of from several hundreds to several thousands, all things considered in compressing and in using, are possible and practicable in the face of heat and refrigeration, with the assistance of compounding, tripling, quadrupling and what not; that is, whether it will pay to employ this vehicle for transporting power developed at a convenient and economical point, and distribute the accumulated energy for use through a system of street cars.

Capitalists who invest money for a return upon the outlay are very careful in considering the enthusiastic, although sincere, views of inventors, and even if it is reasonable to believe that compressed air will eventually take important place in the world's work, the investors who take the responsibility are very much in the position of the man who wanted to know how to tell toadstools from mushrooms, and was advised to eat them and if he did not die, then they were mushrooms. Obtaining, say, 10 per cent., or less, of the heat value of coal in the form of power for available use, is a sure thing, well known, and, from the standpoint of facts, cheap. But putting Professor Tyndall's "mode of motion" into some other medium of transportation and paying toll at both ends of the line, appeals to the man who pays the bills with a force not easily appreciated by the scientist. The losses met with in transforming mechanical energy into electrical energy, and sending it in this form over the trolley wire and into the car motor, or in investing the mechanical energy in the pull of a cable, are more than counterbalanced by many conveniences and economies, and now the hope that some incidental advantages in sight may be realised and still a little better economy be obtained, is attracting attention towards compressed air.

Returning to the above mentioned

mines, it was found by means of indicator diagrams, measurements and other data, that the larger mine of the two was using, at normal temperature of 60 degrees at the surface of the mine, 1,430,363 cubic feet of compressed air, at 60 pounds pressure per square inch, per twenty-four hours; and that the smaller mine was using 444,922 cubic feet per twenty-four hours at the above temperature and pressure. The power indicated at the former was 196 horse-power, and at the latter, 47 horse-power.

The air was compressed by two duplex compressors, each having two cylinders 32 inches in diameter and of 60 inches stroke, and after allowing for the shrinkage of the air by cooling from the temperature developed by compression, to the normal temperature of 60 degrees at the surface of the mines, it was found that the compressors delivered into the conduit 2,378,945 cubic feet of air at 60 degrees temperature and at 60 pounds pressure per square inch. From careful observation and experiment it was decided to allow a loss of 2 per cent. in passing from the compressors to the mining locations, although it is very probable that this allowance will scarcely cover the leaks from expansion joints and other causes; but the net volume of air delivered at locations at 60 degrees and 60 pounds, is taken at 2,331,366 cubic feet.

The discrepancy of 456,081 cubic feet, which was found to exist between the total air estimated to have been consumed, and the net quantity delivered at the locations by the compressors, shows the losses or wastes from leaks of piping and machines, or uses not accounted for; and in summing up there was charged to each mine a proportion of the loss, corresponding to its proportion consumed, making the gross figures and percentages of each mine as follows:—

Larger mine	1,778,132	cubic feet.
Smaller mine	553,234	"
Larger mine	76	per cent.
Smaller mine	24	"

The above percentages of consumption are the same in relation to the air actually accounted for; in other words, the net consumption agrees practically with the gross quantity as far as percentage is concerned.

The following details exhibit the manner of reaching conclusions in the matter:— Each pump and engine was charged with air at the average rate of motion for the time covered by the investigation. The hoisting and incline engines were carefully timed, and the number of revolutions required to perform the respective operations in each case were noted. The indicator diagrams from which the consumption of air was calculated for hoisting and inclined engines, were selected from those taken when the engines were doing their average work.

The average work done per day was reached by means of the mining company's records of hoists made during the month. The distance lifted and, hence, the revolutions of the engines per lift, were carefully averaged from the depths of the levels in the different cases, so that after the amount of air required by each engine for one revolution was determined from the average work, it was only necessary to multiply this quantity by the number of revolutions necessary to perform the average lift, and then multiply this result by the average number of lifts per twenty-four hours as determined from the records of the month.

The machinery driven by the compressed air consisted of Reynolds-Corliss automatic engines, Knowles and Cameron direct-acting pumps, Lidgerwood and Rochester hoisting engines, and rock drills of the Rand and of the Ingersoll makes. Samples of the indicator cards accompanying the report submitted are not now available, but they closely resembled regular steam cards, with the possible exception of being a little more perfect in some respects, on account of the air being a perfect gas and not subject to condensation, although the contraction of the air under five or six expansions in a Reynolds-Corliss engine, due to the extreme fall in temperature, was plainly discernible.

Some very interesting details came to notice in the automatic engines, illus-

trating some features peculiar to compressed air. For example, under six expansions refrigeration would take place to an extent that would result in the formation of ice, or frost upon the back cylinder head even when the sun was shining directly upon it, and it was deemed advisable to keep a little steam going into the exhaust passage beneath the cylinder. A successful experiment was tried to admit the atmosphere into the cylinder when the expansion curve under a light load went below the atmospheric line. This was accomplished by attaching large check valves to each cylinder head opening inwards towards the interior of the cylinder, and the result was that the expansion curve changed to a horizontal line upon reaching the atmospheric pressure and so economised a trifle in power, as the actual diagram down to absolute vacuum would, of course, be greater upon the driving side of the piston, and thus dictate a slightly earlier point of cut off. The automatic cut-off engine is pre-eminent in usefulness in the employment of compressed air, and, in fact, all power generating engines will, no doubt, run longer and with less leakage and repair with compressed air than with steam, on account of the absence of heat, the philosophy of the matter being that lubrication can be more effectively applied.

Another interesting item was the evidence of more or less moisture in the atmosphere, furnished by the varying tendencies towards the formation of ice in the exhaust cavities of the various machines. When the investigation commenced, the weather was cold, and the air was dry and clear; but after about two weeks had passed, the weather became warmer and the snow began to melt, a state of things promptly shown by the appearance of increased quantities of ice, and, in fact, the appearance of ice where formerly none had been seen.

A Knowles No. 10 mining pump had been running along with hardly any ice at all showing at the exhaust outlet, but after the snow melting had begun, ice formed in such quantities that it became necessary to occasionally burn waste at the opening to keep it clear. The indicator diagram from this pump, and, in fact, from all the pumps, took the form of a perfect parallelogram, with a terminal of about 40 pounds, and when the exhaust let go and the pressure of the air fell in a straight line from 40 pounds down to atmospheric pressure, the refrigeration was simply terrific. A long centigrade thermometer was so discouraged that, when placed in one of these exhaust openings, the mercury went clear down into the bulb and refused to exhibit how cold the air really was.

The following is a summary of the quantity, and the power transmitted:—

AT THE COMPRESSORS.

Cubic feet of air at highest temperature and pressure	3,199,968
Cubic feet of air at highest temperature, 60 lbs. pressure	3,867,000
Cubic feet of air, 60 degrees temperature, highest pressure	1,966,880
Cubic feet of air, 60 degrees temperature, 60 lbs. pressure	2,378,945
Cubic feet of air taken at suction pressure	12,287,878
Cubic feet of air, lost action at ends of strokes	511,994
Cubic feet of air, displacement of pistons	12,799,872
Effective capacity at suction pressure	.96 per cent
Effective capacity, 60 degrees and 60 lbs.	2,378,945
Loss or shrinkage from temperature at instant of compression to 60 degrees	38½ per cent
Power indicated by actual diagrams from compressors	1169 H. P.
Power indicated by isothermal diagrams from compressors	931 H. P.
Power lost by cooling of air	238 H. P.
Power lost by cooling of air	20.59 per cent.
Friction of compressors and driving machinery	175 H. P.
Friction of compressors and driving machinery	15 per cent.
Total power given out by the water with the compressors at 40 revolutions per minute	1344 H. P.

According to well known laws, the temperature of the air in the compressor cylinders at the instant of highest pressure was 393 degrees F. A thermometer, placed in the outlet chamber, indicated 285 degrees, but time of observation being of short duration, and the instrument not being protected at its upper end from the temperature of the room, the thermometer would naturally show a lower reading than the actual temperature of the compressed air in the force chamber; in addition to this the water jackets would prevent the highest temperature at the instant of compression reaching the thermometer.

AT THE MINING LOCATIONS.

Diameter of the conduit, 24 inches.
Length of the conduit, 2½ miles.
Mean velocity of compressed air through conduit, 43½ ft. per second.
Quantity lost in coming to locations, 47,579 cu. ft.
Net delivery at locations, 60 degrees and 60 lbs., 2,331,366 cu. ft.
Proportion of air realized at locations, 60.28 per cent.
Cubic feet accounted for by diagrams at mines, 1,875,285.
Cubic feet not accounted for by diagrams at mines, 456,181.
Proportion unaccounted for, 19½ per cent.
Of air accounted for the larger mine used, 76 per cent.
Of air accounted for the smaller mine used, 24 per cent.
Loss of power by friction of air in the conduit coming from the compressors to the locations, 1 per cent, or 9.31 H. P.
Net power stored in air at locations, at 60 degrees and 60 lbs. pressure, 921.69 H. P.
Net available power at locations was 68.57 per cent. of total air.
Net available power at locations was 78.83 per cent. of compressors.
Air delivered at locations per net H. P. per 24 hours, 2531 cu. ft. at 60 degrees and 60 lbs.
Air consumed at larger mine by steam pumps and hoisting engines, not including Corliss type, per H. P. per 24 hours, 9748 cu. ft.
Same for Reynolds-Corliss engines, 4394 cu. ft.
Average for all engines and pumps at both locations, 7921 cu. ft.
Total horse-power possible at 7921 cu. ft. per H. P. per 24 hours would be, 294.30.
Horse-power accounted for, 241.36.
Deficiency, 17.9 per cent.
Horse-power possible from air accounted for, 241.52.
Horse-power actually accounted for, 241.36.
Horse-power not accounted for, 0.16.

The compressed air is distributed as follows:—

FIRST LOCATION.

Steam pumps	70.76	Horse-power.
Rock drills	12.25	"
Hoisting engines	23.75	"
Corliss engines	88.40	"
Total	195.16	"

SECOND LOCATION.

Steam pumps	22.94	Horse-power.
Rock drills	5.46	"
Hoisting engines	17.80	"
Total	46.20	"

The Reynolds-Corliss engines consumed 54 per cent. less air per horse-power than the other machines, and at this rate of economy, if it were possible to use the automatic class of driving engines for all purposes, the net volume of compressed air received at the mines would develop 530.50 horse-power as against 294.30 under existing conditions.

The most important fact brought to light by this investigation is the very great loss of power sustained in utilising the compressed air at the locations, and, in fact, it was this apparent loss which brought about the investigation, the impression having been made in the minds of the directors of the mining company, that the compressors were not doing as much work as they ought to. The compressors proved to be doing all that could have been expected of them, but the losses, both inevitable and avoidable, were greater than anticipated.

Only 31.9 per cent. of the stored up power could be realised at the rate per horse-power shown, and only 26.15 per cent. actually was realised, the difference between these two amounts indicating the waste or leakage. This immense loss of power is easily explained by the fact that the compressors delivered only 2531 cubic feet of compressed air per horse-power, whereas the average consumption was 7921 cubic feet per horse-power. Under the most favourable conditions, with two or four large engines to use all of the air to the best advantage, there would inevitably be a loss of at least 25 per cent. from the cooling by expansion in the cylinders. It would not be safe with single-stage compressors to reckon upon more than 40 per cent. of the total power at the initial point, under the very best conditions of automatic engine practice in using the air; and with ordinary slide-valve engines and direct-acting steam pumps such as were used in the above cases, not more than 18 per cent. of the total power would be derived from the air at the point of employment.

Of the 19½ per cent. of the compressed air not accounted for, a very large proportion most probably escaped through leaks practically inevitable in a plant of this class; and as an indication of the possibilities in this direction, the following enumeration is made of places where the air at least might have a chance of getting away in unknown quantities:—280 stuffing boxes; 134 stop valves; 60 pistons; 100 slide valves; 21 auxiliary valves; making altogether 595 places of possible escape.

The lively interest now being directed towards the compression and use of air for power purposes is both natural and logical, and the reduction of the losses from the generating of the initial power

to the employment of the air, by means of multiple operations bids fair to bring this very attractive, cleanly, and in many ways desirable mode of energy into prominence upon a large scale. Perhaps the saving in the construction and interest accounts may even now more than balance some of the losses which at present seem to be unavoidable; at least the outlook for compressed air now is certainly as good as the prospects were for electricity fifteen years ago.

If the losses have been reduced to one-half in compressing, as is now claimed by those who ought to know, it may pay some one to invest money enough to find out the facts in the matter.

MAINTENANCE AND REPAIR OF MARINE BOILERS.*

By J. F. Walliker.

ONE of the principal points to be considered in the paying life of a steamer is the boiler question, as care exercised in ordinary upkeep from the first becomes a marked factor when increase of years and adoption of newer types of vessels bring down to almost the vanishing point the necessary margin of profit which tempts the capitalist. It may be specially interesting to note in this respect that on December 31, 1895, the total number of steamers registered in Cardiff alone numbered 290, with a total tonnage of 183,900 registered tons. In bringing forward for consideration a few points for discussion, founded principally on the writer's experience, it will not perhaps be necessary to say that the subject matter is confined entirely to the present cylindrical type—or Scotch boiler—as, it is understood, that with few exceptions this is in universal use. Whether the future boiler of the mer-

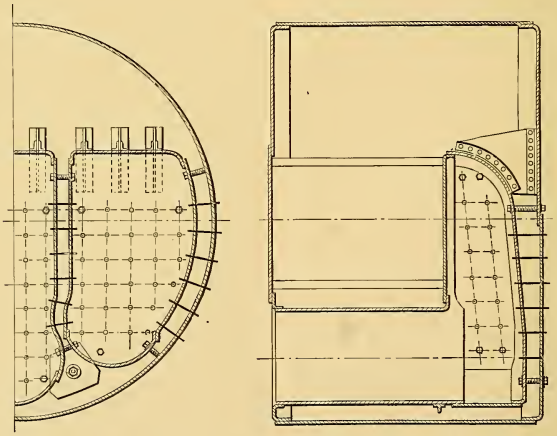


FIG. 1.

* A paper read before the North-East Coast Institution of Engineers and Shipbuilders, England.

cantile marine is or is not to be of the water-tube pattern does not appear to be in any way settled. That this boiler is highly successful for certain classes of vessels is an undoubted fact, and one of the principal objections made to its adoption has been for some time done away with in the universal use, in the best and most modern cargo boats, of apparatus for supplying fresh water for auxiliary use. The working pressures of marine boilers is gradually getting higher and higher, and, as we appear to have nearly reached the limit of thickness in the flat plates of the present

maintenance and repairs, there appear to be two factors which have intimate relations with them, and which must assist or retard the ultimate success of the most careful and elaborate supervision, and these are design and manufacture.

Design.—The writer would place accessibility in the forefront of all boiler design. What is usually seen in ill-designed boilers? Tubes and stays brought close to the furnace crowns and shell of boilers, stays placed in waterways, at the sides of mud hole doors, etc. Wide spacing of stays at the combustion cham-

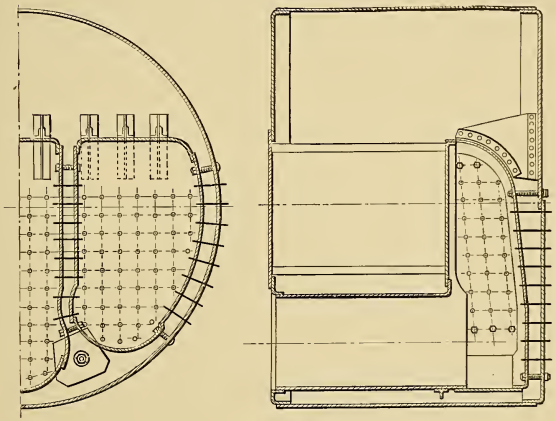


FIG. 2.

boiler, some modification in form will be necessary.

The increase of pressures will be easily seen from the subjoined table corrected up to the middle of last year:—

Table Showing Increase of Pressures in Main Boilers of Vessels Classed in Lloyds' Register in 1885 and 1895.

BOILER PRESSURE.	No. of Vessels, 1885.	No. of Vessels, 1895.
Below 60 lbs.	122	40
60 lbs. to 70 lbs	673	217
70 lbs. to 80 lbs	1,326	666
80 lbs. to 90 lbs	1,650	1,101
90 lbs. to 100 lbs	346	397
100 lbs. to 110 lbs	102	321
110 lbs. to 150 lbs	33	213
150 lbs. to 160 lbs	34	517
160 lbs.	14	2,200
Above 160 lbs.	3	416

Before passing to the main question of

ber back seems to be a point often omitted when designing a boiler, and there appears to be no reason why a limit of 9-16-inch or 5/8-inch should be imposed on a flat plate at this part when a 3/4-inch one is in successful use in an equally hot or hotter part, viz., the furnace. The difference in the staying of this part with a 9-16-inch and a 3/4-inch plate can be easily seen from the sketches on this page and the one preceding, which show a marked difference in favour of the thicker plate; actually 264 stays with a 9-16-inch plate and 156 stays with a 3/4-inch plate.

Management.—The superiority of the system upon which boilers of the pres-

ent day are worked, compared with that of fifteen or twenty years ago, shows enormous strides in the general condition in which they are found. At that time twelve years was usually looked upon as a good life for a marine boiler, and with the lighter scantlings, indifferent workmanship, and general want of knowledge in treatment, this remark was more or less perfectly true. With, however, the present better knowledge, it is not a bold assertion to make that thirty years will not be an excessive age, and more especially when it is remembered how many boilers of over eighteen years of age of the older type, and under the newer conditions of knowledge, are still in existence, and doing good work. The chief items in internal deterioration are:—(1) Pitting and corrosion, (2) overheating of plates due to scale, etc.; and consequent (3) wasting and (4) distortion. The chief factors in external deterioration are:—(1) Leaking at landing edges and rivets.

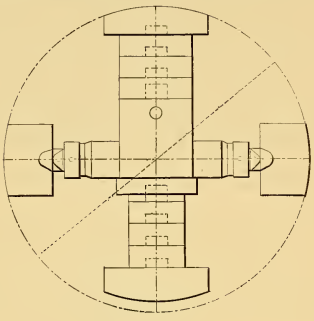


FIG. 3.

Application of Zinc and Soda.—The cause of pitting and corrosion has been discussed almost *ad nauseam* in every society taking an interest in boiler deterioration, but it is now a matter of universal knowledge that its harmful effects can be entirely obviated by cleanliness and care, and by the use of zinc and common soda. These are applied under various patent designations, but the resultant is the same in lasting benefit to the boiler. The almost entire disuse of oils for the pistons and valves of engines has materially contributed to the present good order of the interiors, and it cannot be too much emphasised how well the modern engine runs under these conditions. It has been claimed as a factor in the success of the water-tube boiler that the cylinders and valves of the engines are run without oil, but this system of only using the small portions passed in from the piston and other rods has long prevailed in many of our best cargo boats. The evaporator has been already noted, and the advantages of its useful adjuncts; the feed heater and strainer have also been fully discussed.

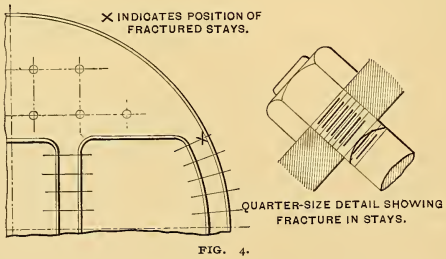


FIG. 4.

Maintenance and Repairs.

Setting Back Furnaces.—Among the numerous items of boiler repairs there have, unfortunately, still to be faced that of occasional distorted furnaces, and these, when found seriously out of shape, have to be dealt with either by replacing or by being forced back into

their original shape. The usual procedure is to cross-stay the furnace at right angles to the direction in which the force has to be applied, properly support the under side of the furnace, and then to restore to shape by pressure, going over the parts again and again. Where the deflections have taken the form of pockets, a hole has to

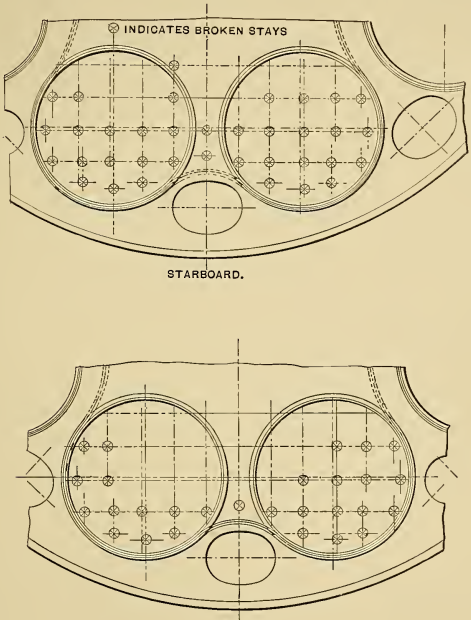


FIG. 5.

be drilled in the centre for the gathering of the metal, and no difficulty has been experienced so far, even in very hopeless-looking cases. A hydraulic jack, with side arms and chocks, adapted to different diameters—Fig. 3—has been in successful use for some time, and it need not be added in this age of steel boilers that these operations are carried out without the aid of heaters.

Failure in Plates and Stays.—Some few years ago engineers were troubled with what were than considered mysterious cracks in shell plates of double-ended boilers, and also in combustion chambers. The origin of these has been fully investigated, and their causes are well understood. Of more recent interest are the cases of fracture of short combustion chamber stays, generally occurring at the backs at bottom, and occasionally in double-ended boilers at the top row in the wings. Examples of these are shown in Figs. 4 and 5, and the causes are apparently due to unequal expansion. It is to be noted in each case that the stays have broken off next to the shell, that they show no signs of elongation, that the fracture is nearly square, and that no further trouble has occurred after they had been once renewed.

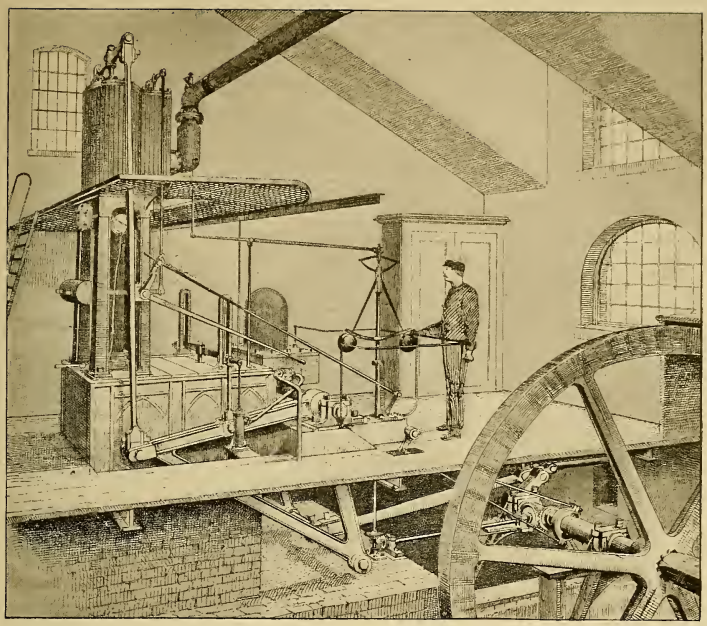
Boiler Tubes.—A question has often arisen as to the condition in which the tubes of a boiler ought to be kept,

whether it is better to let them run uncleaned, or with the same care and attention bestowed on them as the furnaces, and the question, being rather an interesting one, may be stated in the following way:—The percentage of tube surface in the heating surface of a boiler is about 85 per cent., and the effective heating surface 40 per cent.—allowing 30 per cent. for furnaces and 30 per cent. for combustion chambers, etc. Now, if we take this at 20 per cent. instead of 40 per cent., what becomes of all this efficient heating surface when the tubes have from ¼-inch upwards of hard scale on them, and does it not seem to point to true economy in working to have this important boiler factor kept at its highest state of efficiency? With the more modern boiler this is beginning to be seen, but, with few exceptions, the older type of boiler—and this the one, too, that can least afford it—is allowed to be neglected until the corrosion, which has all the time been at work under the scale, eats through the metal and causes delay and expense by a general total renewal of the tubes at the age of six years and upwards. The writer is cognisant of one firm of shipowners who consistently cleaned their tubes, and their small coasting vessels, of 1500 tons to 2000 tons, had never in one instance, up to a short time ago, retubed a single boiler, several of which had been running in continuous work over eighteen years.

Guards to End Plates.—A point that might be added with regard to end plate guards is the absolute necessity of having them either fitted altogether separate from the boiler end—which is the best practice—or so made that soot or other matter is unable to gather there to the serious detriment of the plate and contiguous stays. The whole of the deterioration observable in this part could, in the writer's opinion, be absolutely done away with by attention to this most necessary detail, and all wasting can invariably be traced to the presence of undue heat.

Auxiliary Boilers.—Speaking generally, the principal wear noticeable in auxiliary or donkey boilers is due entirely to the effects of heat and damp on the shell, this being most noticeable in the cases of vertical boilers in stokeholds where the wasting is invariably to be found on the side next to the main boilers. The cure for this is so obvious that it would be unnecessary to mention it were it not for the fact that so many boilers are rapidly depreciating for the want of a little protection when out of use.

Boiler Covering.—It may seem out of the scope of this paper to mention tanks under boilers in connection with it, but it seems to have escaped general notice that it is as necessary to cover the bottom of a boiler as it is the top. It goes without saying that if a boiler could be kept perfectly cool, the extensive deterioration in tanks at this part would cease. The proper and efficient covering of the shell at the bottom has made a marked improvement in the case of the steamers which have, so far, adopted it.



AN OLD WATT ENGINE AT THE SOHO FOUNDRY, ENGLAND.

A FEW STEAM ENGINE CONTRASTS.

By George L. Clark.

IT does not take long to make an interesting collection of literature pertaining to any particular branch of engineering. All kinds of data constantly present themselves, and it requires comparatively little labour to properly classify and permit them to expand into references of most convenient and useful character. It is, in a measure, surprising to find how instructive such accumulations often become in a short time. They show very distinctly the trend of thought and action in different departments of engineering and in different minds, at different periods, too, perhaps, and are suggestive in many ways.

From such a collection of steam engine literature the illustrations and particulars, given in the following pages, have been taken. They refer to a number of designs, old and new, of widely varying characteristics. The first two of the illustrations are from *The Engineer*, of London, and show a type of engine which very few of the present generation can have seen. It was one of the engines of the venerable Soho

Foundry, in England, and was probably designed by the late James Watt about seventy-five years ago.

The peculiarity of its design, according to *The Engineer*, caused it to be known as the "bell-crank" engine. In all probability the dual work with which it was called upon to deal was the necessity which brought forth its general arrangement, adapted, as will be seen, both for pumping and tool driving.

With regard to the former capacity, the general view will show the lower arms of the bell-crank levers coupled by a cross bar, from the centre of which the main connecting rod transmits motion to the main crank, and thence by another rod to a second bell-crank lever, which works a lift pump in a well, shown in the diagram on this page.

It is said that the vacuum of this engine was so good that it could boast of enough and to spare, and that a 6 inch pipe was connected with the condenser of a 24 horse-power beam engine in an adjacent building for the purpose of reducing the inefficiency of the latter.

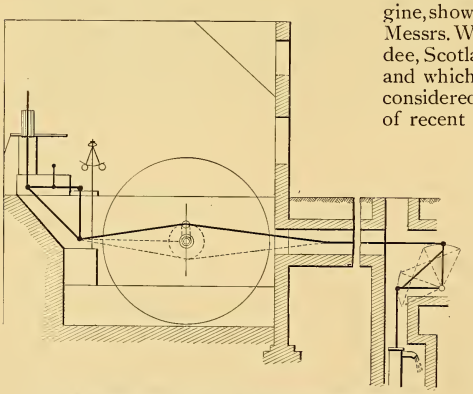


DIAGRAM SHOWING THE CONNECTIONS BETWEEN THE ENGINE AND PUMP.

In all other respects, its character seems to have universally been that it was ready for work night and day for weeks together. Its working pressure was that usually adopted in those far-off days, viz., 10 pounds. The main shaft, which is square, is below the ground level, and is carried upon pedestals supported upon brick piers, and the rocking shaft upon which the bell-crank levers are keyed has its bearings just above the ground level.

The air pump is worked from the horizontal arms of the side levers, and the eccentric rod is thrown out of gear by means of the disengaging apparatus, so much used in those days, which acts in opposition to the gravity of the rod.

Diameter of cylinder	= 18in.;	stroke	= 26in.
Do. air pump	= 15in.;	do	= 11in.
Do. well pump	= 10¾in.;	do	= 19in.
Do fly-wheel	= 11ft. 6in.		

The well pump is about 43 feet from the main shaft, and its lift is about 15 feet, the stroke of 19 inches being due to unequal leverage of its bell-crank arms. The slide valve is worked from the top of the steam chest by side rods connected with levers on a rocking shaft off the main frame, and the engine is controlled by the old type of fly-ball governor—one of Watt's minor, yet most essential inventions.

In bold contrast with this venerable relic stands the triple Corliss beam engine, shown on the opposite page, built by Messrs. W. B. Thompson & Co., of Dundee, Scotland, for a cotton mill in Bolton, and which by many engineers has been considered one of the most astonishing of recent things in steam engineering. There are three cylinders and three beams, the cylinders standing on the floor level, accessible all over. Everything is in equilibrium; the foundations are light; and there is very little detail of framing or mechanism.

The remarkable feature of the engine is the beam arrangement. Beam engines have been called old-fashioned, even to the point of ridicule. Their use on American river steamers, for example, has called out a good deal of adverse criticism from English steam engineers, who have contended that American practice was half a century behind, and that beam engines were superseded in English practice long ago;

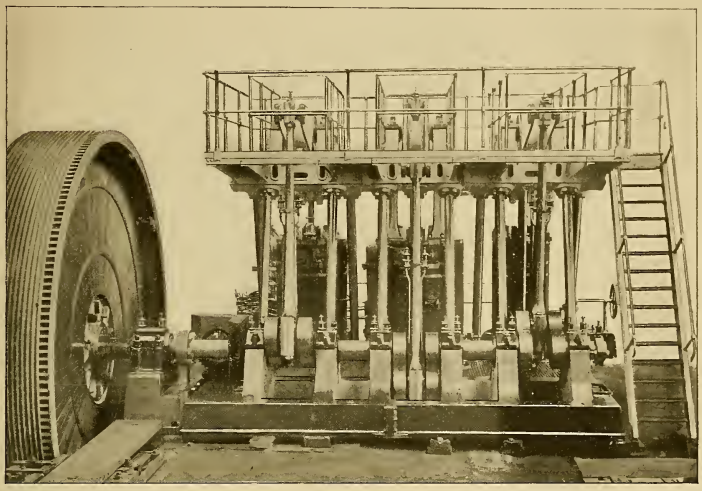
but, like some other superseded inventions, they come back again when innovations have run their course.

The popular idea of beam engines in America as well as in England,—that they are nearly obsolete, and have given way to better forms of construction,—is not true, and never can be until the same functions are attained in other designs,—not for all uses, but for a large share of cases.

The things especially referred to are that the reciprocating elements of beam engines are in equilibrium, balanced on a scale beam, so to speak; the piston is suspended in the cylinder, so as to wear equal on all sides, and the links or connections make only a slight angle, so that there are no considerable lateral strains. The same remark applies to the crank connection, which is long without a corresponding waste of room.

The various pumps are worked directly from the beam with only motion rods for gearing, and the machinery, as a whole, occupies a long narrow space, fore and aft in vessels, and is set on edge, so to speak. The principal strains are taken up on vertical lines, falling in the plane of best resistance, that is, normal to the foundation.

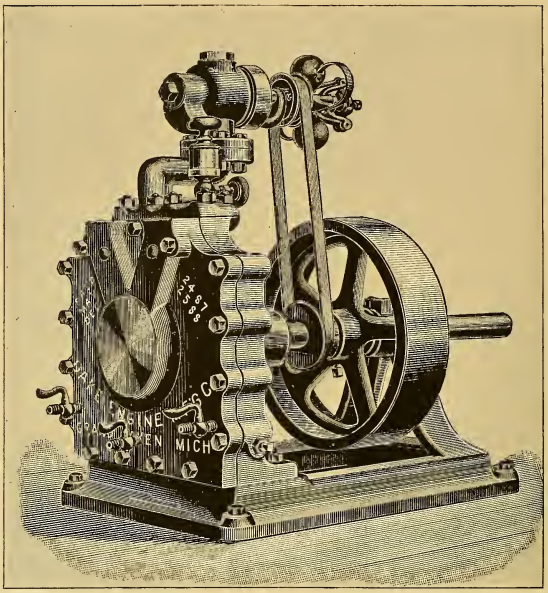
The engines shown in the engraving were driven for trial at more than one hundred revolutions, when loose and resting on blocks. Their working rate is much less, and the foundations required are not more than one-half as expensive as they would have been to accommodate directly-connected engines. This latter feature is, however, due in a great measure to the triple beams and connections, with consequent balancing, in a great degree, of the reciprocating strains.



TRIPLE CORLISS BEAM ENGINES. BUILT BY MESSRS. W. B. THOMPSON & CO., DUNDEE, SCOTLAND.

The valve motions are extremely simple, and the main parts, requiring care and adjustment, are all within easy reach. The cylinders stand on the floor, and an attendant can go all around them. The convenience is remarkable, and is not attainable in the same degree by any other arrangement.

Radically different from the engine just considered is that shown in elevation and detail on the next two pages, and known as the Dake square pis-



SQUARE PISTON ENGINE. BUILT BY THE DAKE ENGINE CO., GRAND HAVEN, MICH., U. S. A.

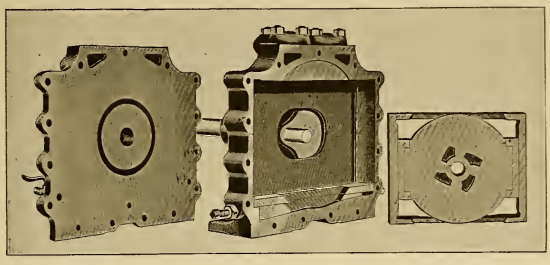
ton engine. It is not a rotary engine as its appearance, at first glance, might indicate, but a double regular reciprocating engine of very compact make. It is shipped by the builders ready to bolt down and set to work.

In the upper one of the illustrations opposite, the two pistons are removed, showing the interior of the case with the crank in position. The latter revolves in a special chamber.

The illustration below shows the pistons in their proper position on the crank and carried to the extreme right hand. Both pistons have a horizontal movement, sliding from side to side, and at the same time the inner piston, to which the crank pin is attached, has a vertical or up and down movement, the two movements imparting rotary motion to the crank. The steam supply to the pistons is effected through channels in the cover, leading down to the centre from above, one opening into a central aperture, and the other into an annular opening. Four channels are cored through the inner piston, two leading to the top and bottom, respectively, and one to each end of the inner piston; these latter also lead through the ends of the outer piston.

Four ports, corresponding with the channels in the interior of the inner piston, are cut through the face (or side next to the cover), of the inner piston, in the proper position to register over the central aperture in the cover. The steam, entering the port in the inner piston, through the central aperture of the cover, imparts motion to the crank, the port passing over the annular ring and exhausting into it after having done its work. There are four distinct impulses of steam to each revolution of the crank and the arrangement of the ports to the crank is such that each impulse of steam is given at a point where it has the greatest power.

The inner piston is fitted with phosphor bronze slides that admit of a thin piece of tin or sheet iron being inserted when the wear is sufficient to allow it. A wedge-shaped plate, on which the lower slide rests, is arranged with set screws on the outside of the case; this keeps the piston steam tight top and bottom.

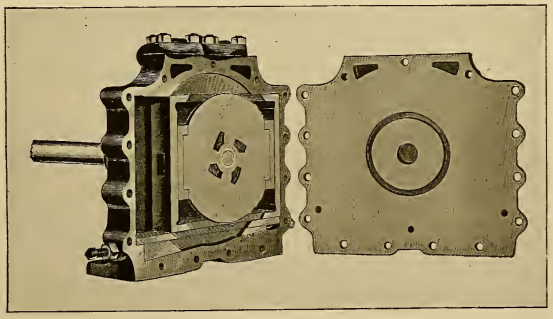


THE CYLINDER OF THE DAKE ENGINE, WITH PISTONS REMOVED.

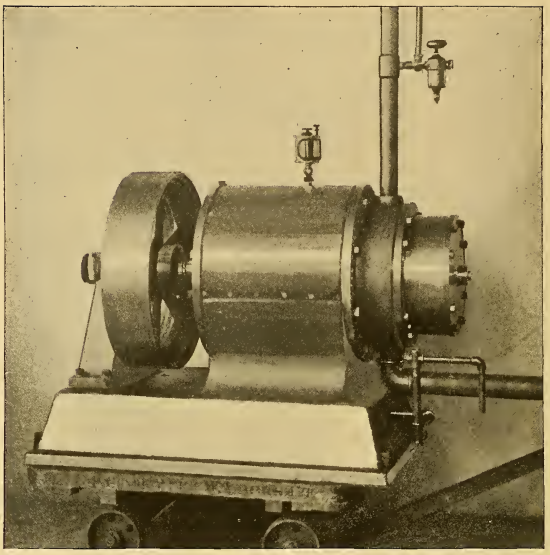
The Dake engine is recommended for direct connection at either low or high speeds, having, it would appear, given satisfactory results in such work in many cases. In driving centrifugal pumps, for example, it has been known to perform admirably under severe conditions.

The Knickerbocker engine, like the Dake, is not a rotary motor, despite its appearance, but is similar, essentially, to a plain reciprocating slide valve engine, with pistons running in cylinders in the ordinary way. The difference is that instead of one large cylinder, there are four small ones, set at the corners where the large one would be, with the cross head hung at the back of them on a large ball and socket connection, making the crank pin describe the lines of a cone instead of the lines of the crank, getting rid of centres and having a constant push on the crank pin all the time.

The large socket connection carrying the cross head has a little crank pin on the other end of it which revolves the valve shaft. The eccentric is fastened to this shaft and in the steam chest between two walls. The valve is loose around the eccentric, and the latter revolves while the valve, being larger in



THE PISTONS IN THEIR PROPER POSITION.



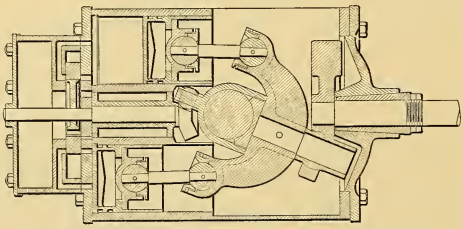
ENGINE BUILT BY THE KNICKERBOCKER ENGINE WORKS, HARTFORD, CONN., U. S. A.

diameter, simply slides back and forth. The connections between the cross head and the pistons are all ball and sockets, and their motion is that of a figure 8.

The nature of the design enables everything to be brought into very small space. The engine needs no foundation and can be placed anywhere both for stationary or marine service.

A vertical triple expansion engine, with several novel features, is shown on pages 463 and 464, having been built by Messrs. Bumsted & Chandler for Messrs. Cadlemey's mills, near Birmingham, England. The illustrations have been reproduced from *Engineering*, of London, from which also the following data are taken:—The engine is intended to indicate 120 horse-power, with steam at 180 pounds initial pressure. It is of the inclosed type, with cylinders 11 inches, 15½ inches, and 22 inches in diameter by 13 inches stroke.

The three pistons are mounted on a single rod, which at its lower end is secured to a cylindrical cross head. The valves are similarly mounted, and are four in number. The lowest one of the set controls the exhaust port, and prevents the vacuum destroying the cushion steam above the low-pressure piston, thus securing that the connecting rod is always in compression, and rendering the engine silent in working.

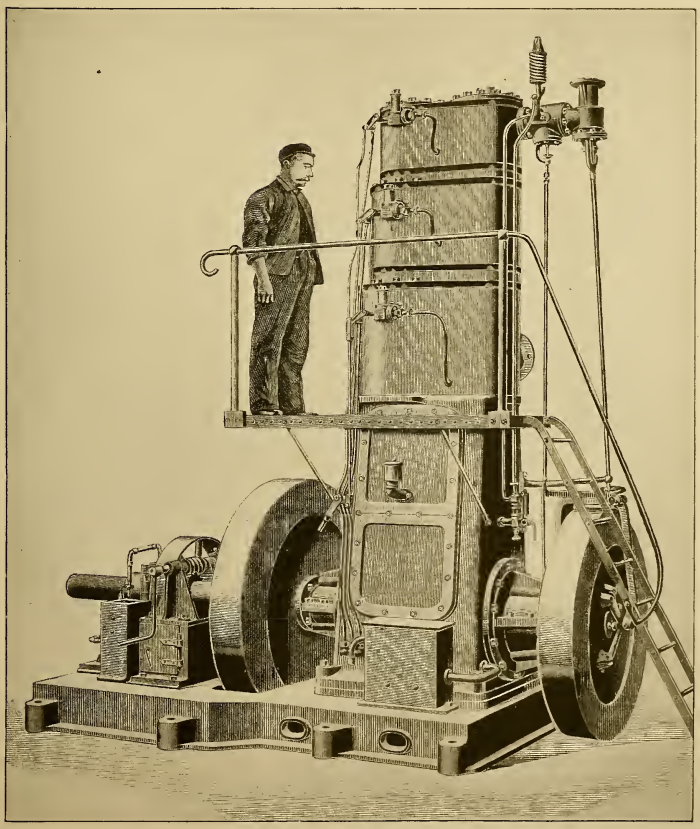


LONGITUDINAL SECTION OF THE KNICKERBOCKER ENGINE.

The other valves are of the solid piston type. The engine works on the Cornish cycle, the exhaust steam from the top of each cylinder passing first to the bottom of the same cylinder before it enters the next cylinder. Drainage is secured by the presence of a series of small holes near the bottom of each cylinder, which are uncovered by the pistons when in their lowest positions. All water thus passes continually downwards, and finally is delivered to the condenser.

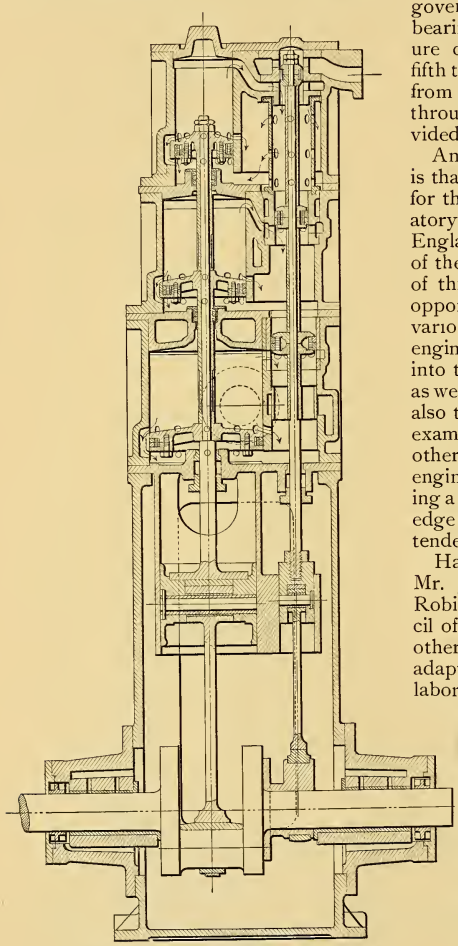
The turning and starting gear is fitted to a prolongation of the bed plate, and to increase the efficiency of the lubrication in the crank chamber, splashers are attached to the crank webs which throw the oil to the top of the casing. The exhaust steam is entirely excluded from this chamber.

One of two steeple compound engines, built some time ago by the Fitchburg Steam Engine Company, of Fitchburg, Mass., for the Oakland, Cal., Gas, Light and Heat Company, is shown on



CHANDLER'S TRIPLE EXPANSION ENGINE. BUILT BY MESSRS. BUMSTED & CHANDLER, HEDNESFORD, ENGLAND.

the opposite page. The cylinders are 16 and 27½ inches in diameter and of 20-inch stroke. It runs under 140 pounds of steam, and develops about 400 horse-power at 210 revolutions.



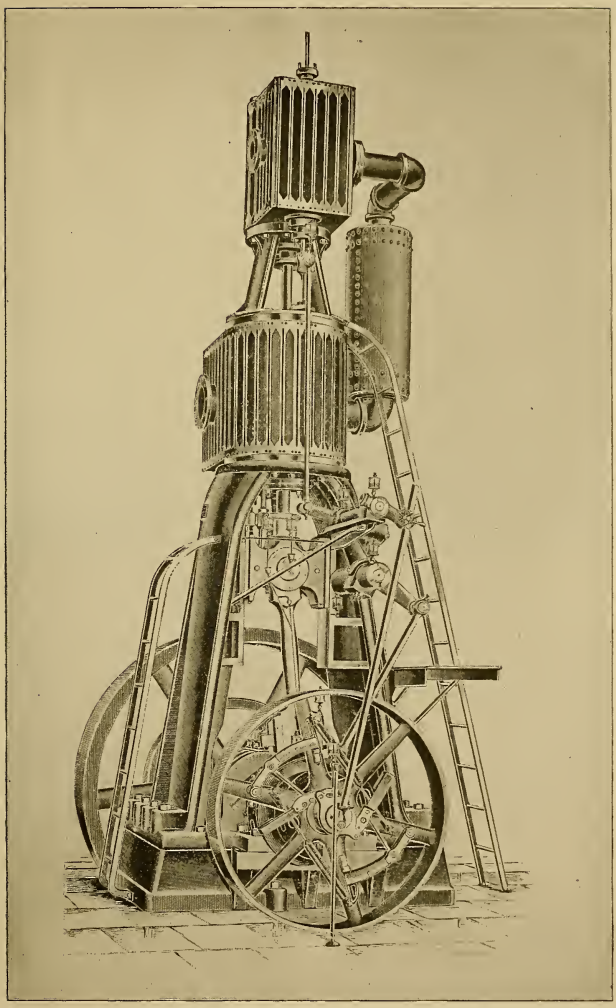
SECTIONAL VIEW OF CHANDLER'S ENGINE.

The cylinders are jacketed with non-conducting material and then covered with cast iron lagging. The valve of the high-pressure cylinder is operated direct from the shaft governor, giving a variable cut-off from zero to two-thirds of the stroke, while the low-pressure cylinder is operated by a separate adjustable eccentric, placed between the governor case and the adjacent shaft bearing. The cut-off in the low-pressure cylinder can be varied from one-fifth to two-thirds stroke. The exhaust from the high-pressure cylinder passes through a steam-jacketed receiver provided with a non-conducting covering.

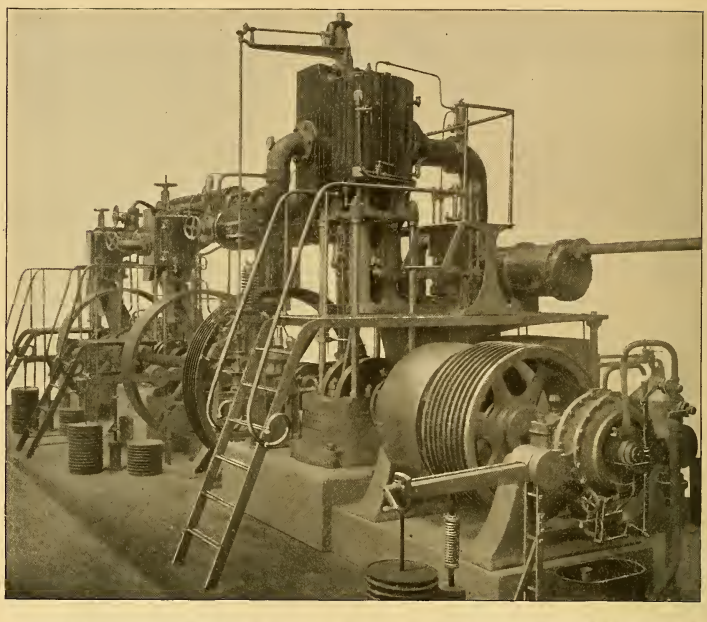
An engine of rather special interest is that built for experimental purposes for the Whitworth Engineering Laboratory, at Owens College, Manchester, England, by Messrs. Mather & Platt, of the same city. The primary purpose of this engine is to afford the students opportunities of practice in making the various measurements involved in steam engine trials; to afford them an insight into the action of steam in the engine, as well as of the mechanical actions, and also to render them familiar with good examples in steam engine design. Another purpose, however, which such an engine should serve, is that of supplying a means of research by which knowledge of the steam engine may be extended.

Having regard to these two purposes, Mr. John Ramsbottom and Mr. John Robinson were appointed by the Council of Owens College to select, amongst other appliances, the steam engines best adapted for the special purposes of the laboratory. They decided that the engines, while as far as possible representing in their principal members the most approved existing practice in steam engine construction, should be specially designed to afford the utmost facilities for experiments on the use of steam throughout the entire range, and, if possible, beyond the limits hitherto accomplished in practice.

In describing the engine some time ago in a paper before the British Institution of Civil Engineers, Professor Reynolds explained that as best meeting this demand it was decided to have three engines, working on sepa-



A STEEPLE COMPOUND ENGINE. BUILT BY THE FITCHBURG STEAM ENGINE CO., FITCHBURG, MASS., U. S. A.



TRIPLE EXPANSION EXPERIMENTAL ENGINE. BUILT FOR OWENS COLLEGE BY MESSRS MATHER & PLATT, MANCHESTER, ENGLAND.

rate brakes, and that all the engines should be of the inverted-cylinder type, with the walls and covers separately jacketed with steam at boiler-pressure, and so arranged that they could be worked with or without steam in any or all of the jackets. Each engine was to be capable of working with steam at any pressure up to 200 pounds per square inch, to run at any piston speed up to 1000 feet per minute, and to have expansion gear to cut off from zero up to two-thirds of the stroke. One engine was to be supplied with air-pump and surface condenser; the other two engines were to be furnished with alternative exhausts, either into the atmosphere, or into steam-jacketed receivers supplying steam to the next engine, and each of the receivers also was to have an alternative supply of steam direct from the boiler.

In addition to the brake, each engine was to be furnished with a fly-wheel, to act as a belt or rope pulley, weighing about 1200 pounds, carried on a separate shaft with a coupling to the crank-shaft.

The firm of Messrs. Mather & Platt, Salford Iron Works, undertook the preparation of the designs and the construction of special engines and boiler to meet in all respects the wishes of the committee, and spared neither trouble nor expense in carrying out the work. It was entirely owing to the zeal and liberality of this firm that the college was enabled to meet the expense of an undertaking involving so much special work. The design of the engines, shown above and on the opposite page, contains many novelties.

As regards the cylinders, pistons, and valves, Professor Reynolds says there are three noticeable departures.

To obtain completeness in jacketing,

both ends (or covers) were jacketed as well as the walls. To ensure efficiency of the jackets, steel liners were used and the covers were domed, so that the surfaces should free themselves by gravitation from the water resulting from condensation, the water being drained from the lowest point in the jacket spaces.

To diminish the resistance of the passages, these were made abnormally large, the area of the ports being 13 per cent. or 1-7.5 the area of the piston, and the steam chests, too, were very large.

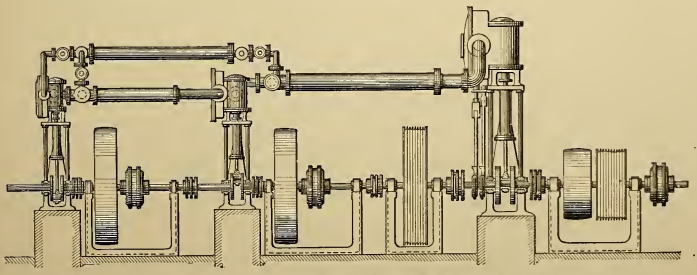
To diminish clearance, the ports were made straight, and the valves brought as close as possible to the cylinder, double valves being used. The pistons were formed to occupy the space in the cylinder, except ⅛-inch clearance at the ends. The result is that in engine No. 1 the clearance space shut in by the main valve is 4 per cent. and 1.7 per cent. more by the rider, and in engines 2 and 3 the clearances shut in by the main valve are 6 per cent., and 2.5 per cent. more by the riders.

To obtain an adjustable cut-off, since at the higher speed the engines were intended to run 400 revolutions per minute, it was practically impossible to use any form of trip cut-off. Meyer expansion valves were used on the backs of the main valves.

The engines are exceptionally strong, being all of them designed to work safely with a pressure of 200 pounds on the square inch, so that the effect of expansion in one cylinder might be compared with compound or triple expansion.

The frames of the engines are of a somewhat novel form, and their purpose may not be immediately apparent. It will be seen, however, that the front cover is cast with a kind of entablature or box, connected with the base plate by four wrought iron columns, placed symmetrically as regards the piston rod. The function of these columns is to withstand the vertical forces arising from the steam pressures on the cylinder covers, and to maintain the axis of the cylinder vertical against any forces; they are not calculated to maintain a horizontal position against lateral forces such as might arise from the action of the slide block. To meet such lateral forces the base plate is prolonged upwards in the form of a strong box standard, the upper portion forming the slide bars, which at the top encircle the piston-rod and pass within, but not touching the box cast on the cylinder cover. Through the sides of this box are four horizontal set screws, which grip the top of the standard, and so transmit any lateral force directly to the standard, as well as admitting of the adjustment necessary to maintain the cylinder coaxial with the slide bars.

In this way the vertical forces are taken symmetrically, and cause no distortion of the engine. The cylinder is held very rigidly by four columns, and the horizontal forces arising from the pressures of steam in the pipe, and particularly from the expansion and contraction of the pipes under a variation of temperature of more than 300 degrees, are taken by the cast iron standard. And, what led more than any-



ELEVATION OF THE OWENS COLLEGE ENGINE.

thing else to this design, all distortion arising from heat is avoided. The heat connection between the cylinder cover at 400 degrees is cut, except for the four columns which are heated symmetrically, and the four set pins which conduct very little heat to the slide bars.

The result appears very satisfactory, the engines running with the slide bars cool at 400 revolutions per minute, doing 100 horse-power with great steadiness.

The somewhat peculiar general arrangement of the engines seems to require a word of explanation. Vertical engines were adopted on account of the much greater accessibility they afford to all the parts; also because they allow of the water from the steam jackets being drained back into the boiler with a less difference of level between the floors of the boiler house and the engine room.

The crank shafts of the engines were raised 3 feet above the floor in order to allow of the floor being kept level and to admit of pulleys 5 feet in diameter; also because 3 feet is a convenient height for working the brakes, oiling and adjusting the gearing. The most noticeable feature in the arrangement of the engines—the distance between them—was necessitated by the alternative shaft connections which it was decided to give them, and particularly by the room required for the belt and rope gearing, and for working the three separate brakes.

The complete shaft consists of seven separate shafts on separate bearings, which can be connected into a single shaft by six special coupling boxes. The shaft immediately on the right of each engine carries a brake, and these brake shafts of the two smaller engines carry 11-inch belt pulleys, 5 feet in diameter, weighing 11 hundredweights, while the brake shaft for the low-pressure engine carries two 15-inch pulleys, 3 feet in diameter, weighing 9 hundredweights, one for a belt and one for ropes. These pulleys act as fly-wheels when the engines are working separately; and, in addition to these, there is between the brake shaft of the intermediate engine and the crank shaft of the low-pressure engine an intermediate shaft carrying a 12-inch rope pulley, 5 feet in diameter, weighing 12 hundredweights, which may be used as an auxiliary fly-wheel on this engine.

The intervals between the engines necessitated by this intermediate gearing are 7 feet between No. 1 and No. 2, and 12 feet between No. 2 and No. 3. These intervals entail no evils in the working of the shaft except the increased friction arising from the additional weight and number of the bearings. This friction may be accurately measured and taken into account in determining the brake horse-power.

UNUSUAL CORROSION OF MARINE MACHINERY.*

By Hector Maccoll.

CORROSION in marine engines and boilers is usually confined to well-known parts, is not rapid in its action, and may be prevented or stopped by the adoption of suitable measures. In a recent instance its action was so widespread, so rapid, and so powerful, as to render a short description of it somewhat interesting to engineers.

The steamer *Glenarm* is a steel vessel of the long raised quarter-deck type, built in Belfast in 1890 for the Antrim Iron Ore Company, and is engaged in their trade between Belfast and ports on the northeast coasts of Scotland and England. She is classed 100 A1 in Lloyd's register, with a deadweight

*A paper read at the recent Belfast meeting of the Institution of Mechanical Engineers.

capacity of about 800 tons, and her machinery consists of three-crank triple engines, with cylinders 17 inches, 27 inches, and 44 inches in diameter, by 30 inches stroke, a three-furnace single-ended boiler of the usual type, loaded to a pressure of 165 pounds per square inch, and a single furnace horizontal multitubular donkey boiler. The shafting and other forgings are all of iron; the boilers are of steel, with iron tubes.

On Tuesday, December 24, 1895, this steamer, carrying a cargo of about 650 tons of burnt ore from Irvine to the Tyne, struck on a rock in the Sound of Mull, and was at once beached in Scallaster bay, where the sea stood a little over her after-deck at low water and close up to her bridge-deck at high water. On the following Monday, December 30, after having been submerged six days, she was pumped out and raised. On the same day steam was got up in the main boiler, but when about 30 pounds pressure had been reached, the steam valve on the donkey pump blew out, and it was found that the copper at the bend of the donkey feed-pipe next the main boiler had disappeared; fires were therefore drawn, and the boiler blown off. On Friday, January 30, 1896, all leaks having been so far reduced as to be under control of the salvage pumps, the vessel left in tow for Belfast, where she arrived early on Saturday morning, all the salvage operations having been successfully conducted by Captain Bachelor, of the Liverpool Salvage Association.

On examination, the machinery was found to present an extraordinary appearance. All wrought iron work was deeply and roughly corroded, and planed cast iron work rendered so soft as to be easily cut with a knife. These unusual effects were undoubtedly caused by the cargo of burnt ore, and the following explanation has been contributed by Mr. S. Courtney, chemist, of Messrs. Francis Ritchie & Sons, Belfast, who investigated the subject at the request of Mr. Robert Browne, secretary and manager of the Antrim Iron Ore Company:—

"Burnt ore is the residue from the manufacture of vitriol from sulphur pyrites, and is generally found to contain about 4 per cent. of sulphate of copper, together with a little sulphate of iron due to the sulphur not having been completely burnt out of the ore, and becoming oxidised into sulphates. The sulphate of copper would be more or less completely dissolved in sea water, and as the latter contains a considerable quantity of chloride of sodium, or common salt, this would react on the sulphate of copper, forming sulphate of sodium and chloride of copper. The sulphate of copper and chloride of copper are both soluble in water, and a solution of either or both dissolves wrought iron and cast iron. The chloride is more energetic in its action than the sulphate, but in time a solution of either, no matter how weak, will dissolve an atom of iron for every atom of copper present. Every hundred tons of cargo contained as much sulphate of copper as would, if available, dissolve near 32 hundredweight of metallic iron. The burnt ore might also contain a small quantity of free sulphuric acid, which would combine with the soda of common salt in the sea water and set free hydrochloric acid, and the latter would rapidly act upon copper or brass."

On the condition of affairs being discovered, the engines and boiler, as well as the hull, were at once opened up for survey, the underwriters being represented by Mr. Henry H. West, of Liverpool, and the owners by Mr. James Maxton, of Belfast. The entire work on the hull and machinery was afterwards carried out under the direction of the latter. The general condition of the engines was that wrought iron work had been penetrated by corrosion to a depth of about 3-32-inch, and planed cast iron so softened that ⅛-inch had to be taken off before a hard surface was regained. Surfaces in bearing contact, or with oil between them, and all painted surfaces, were completely preserved. The detailed condition of the various parts, and the measures taken to restore them, were as follows:—

The cylinders had partially filled through the hot well, and from the

drain cocks being open. The lower part of the intermediate cylinder was softened for 12 inches up, and was rebored ¼-inch larger in diameter, and the piston altered to suit. The piston valves and liners in the high-pressure and intermediate cylinders were softened at their lower ends; the liners were rebored, and the valves fitted with new rings. The lower edges of the low-pressure slide valve and face were also softened; the valve was planed, and the lower bar of the face chipped off and replaced by a brass strip, pinned on. In all other respects they were sound and good.

The piston rods and connecting rods were turned all over, reduced 3-16-inch in diameter, and the former fitted with new neck and gland bushes.

The guides had ⅛-inch planed off them before a hard surface was reached; and the guide shoes were lined up to suit.

The valve gear is of the Hackworth type. The valve spindles and various rods were turned all over, to remove the deep pitting; the angle blocks had their planed surfaces reduced ⅛-inch, and the various parts lined up to suit.

The crank-shaft webs were deeply corroded; but as there was ample strength, they were filled with "hard stopping" and painted. The shaft journals and crank pins were pitted longitudinally in the exposed spaces between the white metal strips, and were also pitted transversely at the clearance spaces next the crank webs. These were cleaned out, filled up, and the bearings adjusted. The thrust shaft was much corroded at the exposed parts of the collars and journal; it was turned all over and the horseshoes and bearing were refilled with white metal. The intermediate length of tunnel shafting was much corroded at the exposed part of the journal; and as it was also reduced by wear, a new journal was turned further forward, and the bearing shifted to suit. The propeller and the propeller-shaft were found in good order.

The centrifugal pumping engine was considerably wasted in the rods, guide, etc., and was treated like the main engines. The duplex pumping engine and donkey boiler pump were so seriously corroded as to be useless, and they were replaced by new ones. The brass steam valve and one pet-cock of the duplex pumping engine were curiously wasted into holes; and the check valve and seat on the main boiler had the appearance of some substance, probably zinc, having been sucked out of them.

From the appearance of the donkey copper feed pipe it was feared that all the copper pipes were seriously affected. A similar bend in the main feed pipe was therefore sawn through, but was found to have suffered no deterioration. All the pressure pipes, however, were taken down, tested, and annealed; no defects were detected, and they were all replaced. But in putting together the various steam and vacuum gauges, the small connecting pipes were found in several places to be curiously wasted below the coupling nut.

It is unnecessary to enumerate the bolts, nuts, cock handles, spanners, and such small details, which were wasted into mere shadows of their former selves, and had to be renewed.

The safety valves of the main boiler having been eased when the vessel was beached, the boiler had filled with water, and the condition of both boilers looked serious. The front end plate of the main boiler was considerably wasted; the furnaces, which are of the spiral corrugated type, had corrosive scores running in the direction of the corrugations; and the tubes were covered with a deposit of what appeared to be pure metallic copper. In the end, however, after careful drilling and gauging, it was found that an unexhausted margin remained in all except the tubes. These were all found to be seriously corroded in both boilers, and every tube was therefore cut out and renewed, after which the boilers were satisfactorily tested.

Although the utmost vigilance and care had been exercised in examining as far as possible every point and detail, latent defects might have existed, and it was not with complete confidence

that steam was again raised and the machinery tried. Neither then, however, nor in the months of continuous service which have since elapsed, has the slightest defect been perceived, and the machinery is now, thanks to its thorough overhaul, working with the efficiency and economy which it possessed when new.

The lessons to be learnt from this experience are probably obvious enough. Some of them are for the shipowner rather than the engineer, and, therefore, need hardly be referred to here; but it may be well to emphasise two of the others.

First.—The advantage of having, in marine engines and boilers, a small margin over the the actual requirements for strength. In the various rods, shafts, and similar parts, such a diameter as would allow them to be skimmed up; in the cylinders, valves, etc., such thickness as would allow them to be bored or planed afresh; and in the furnaces, combustion chambers, and stays, a slight excess of thickness over that required by the rules.

Second.—The advantage of good paint. Many engineers prefer polish to paint; but in this instance the latter truly cost little, and was worth much.

HORATIO ALLEN.

A Chapter in American Railroad History.

By Alfred Mathews.

HORATIO ALLEN, whose chief title to popular regard lay in the fact that he acted as engineer, on its trial trip, of the first practical railroad locomotive in America, the "Stourbridge Lion," had, in reality, several better claims than that, to the esteem of the discriminating.

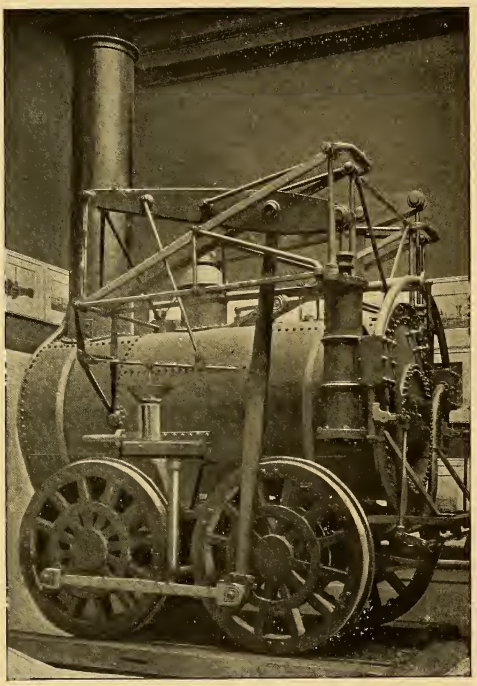
In the ranks of the profession which he followed he was recognised as one of the most accomplished civil engineers of his time, while in wider circles he was acknowledged one of the most productive factors in the pioneering of the American railroad, both in the capacity of general promoter and mechanical expert.

Horatio Allen was born at Schenectady, N. Y., May 10, 1802, graduated from Columbia College in 1823, and immediately engaged in civil engineering. This was his principal occupation during his long life, the active part of which was for the most part spent in the metropolis of his native State, though the works for which he became most famous were achieved elsewhere.

His first important connection was with the Delaware and Hudson Canal Company, that enterprising New York organisation which was a pioneer in opening the immense Pennsylvania anthracite coal region. In 1825 he was appointed assistant engineer for a portion of the canal between the Hudson and Delaware rivers, and in 1827 he was appointed to the same position for the remainder of the canal to the site of Honesdale, Pa., and had in charge also the company's project for transporting coal from the Lackawanna region and the Moosic mountains to the head of the canal on the Lackawaxen. This operation necessitated a railroad,—the same that became, by successive developments, the present famous gravity road of the Delaware and Hudson Canal and Railroad Company,—and it was to meet the problem of transportation upon this pioneer road that young Allen devoted himself to the study of the locomotive, and brought about the importation of the first in America, which was built in England under his directions

and made its initial trip under his personal control, thus securing for him a fortuitous fame as "the engineer of the first locomotive in the country."

This eclipsed, to some extent, the distinction which he gained on other and truer grounds. His attention had been called to the possibilities of the locomotive by the success of George Stephenson and the subject had so grown upon him that in the fall of 1827 he went to England to make a practical study of the "new machine" and incidentally of railroad construction and operation as practiced there. He was commissioned by John B. Jervis, chief engineer of the Delaware and Hudson Canal Company, to purchase the bar or strap iron for the railroad between Honesdale and Carbondale, the chains to be used on the inclined planes, and three locomotives to be run on the railroad levels.



THE "STOURBRIDGE LION," THE FIRST LOCOMOTIVE TO TURN A WHEEL IN AMERICA.

Mr. Allen devised a new method for making the rails, which, though pronounced impracticable by a majority of the iron masters whom he consulted, was finally given a trial at Wolverhampton and proved so successful that all the rails used by the company upon its first road were turned out by that process.

The procuring of the locomotives was the most problematical part of Mr. Allen's commission. He spent several weeks on the Stockton and Darlington railway, studying the construction and operation of Stephenson's locomotives, and finally placed his orders for them, to be built upon the general plan of those he had seen, but with certain improvements of his own invention. George Stephenson built two of these, and Foster, Rastrick & Co., of Stourbridge, the third, which happened to be the first received in America,—the "Stourbridge Lion."

It arrived at New York in May, 1829, and was soon given a test at the West Point foundry, in that city, in the presence of the directors of the company, Mr. Allen (who had returned in the fall of 1828) and several other interested persons. On this occasion it was not upon a track, but merely raised upon blocks, but it was soon to have a further and full trial, for, being shipped by the canal to Honesdale, in Pennsylvania, it was there placed upon the track, and on August 8, 1829, under the guidance

and management of Mr. Allen, it was given its initial trip before a great assemblage of people from the surrounding country.

It acquitted itself to their great delight and wonder and to its engineer's entire satisfaction. Strange to say, although Horatio Allen, who thus acted as engineer of the first locomotive in America, for many years had much to do with railroads, he never again served in the capacity that he had on that red letter day in the history of the American railway. There were then but twenty-three miles of railroad track in the whole United States and Mr. Allen lived until sixty years later, at which time the mileage had increased to over 150,000.

Mr. Allen's next service of importance to the development of railway transportation was in South Carolina. In September, 1829, only a month after his exploit at Honesdale, which consummated his brilliant achievements for the Delaware and Hudson Canal Company, he arrived in Charleston to enter on his duties as chief engineer of the South Carolina railroad, connecting Charleston, S. C., and Augusta, Ga. The question as to what motive power should be used was under consideration and Mr. Allen at once submitted a report in favour of the use of the locomotive rather than horse-power, after making an elaborate presentation of the comparative cost, the estimate as to the former being based on his minute inquiry as to the Stockton and Darlington railway in England.

Mr. Allen showed that the cost of locomotive power was less than that of the horse, but did not content himself with a survey of the facts as they then existed, but took into consideration the probabilities of advancement. His contention for the locomotive, as he quaintly put it, "was on the broad ground that in the future there was no reason to expect any material improvement in the breed of horses, while in my judgment, the man is not living who knows what the breed of locomotives is to place at command."

That official act of Mr. Allen was far more important, if less spectacular, than his running of the first locomotive in America, for it led to the introduction of the locomotive in a practical way and established it as a permanent feature of the railroads in the United States. His recommendation was unanimously accepted by the board of directors of the South Carolina railroad, and their resolution, in Mr. Allen's language, "was the first act by a corporate body in the world to adopt the locomotive as the tractive power on a railroad for general passenger and freight transportation."

Under Mr. Allen's direction the first locomotive for this company was built at the West Point Foundry, in New York, which, having been duly named "The Best Friend of Charleston," was put upon the road on November 2, 1830, and immediately was demonstrated a success. It was the first locomotive built in America and the first that ran regularly on a railroad in the United States (for the "Stourbridge Lion" had not been continued in use). In 1831 Mr. Allen designed a second engine for this road, which was built at the same factory and called "The South Carolina."

Mr. Allen, as chief engineer of the South Carolina railroad, had the road completed, 135 miles in length, in 1833, and it was then the longest continuous line in operation in the world. Mr. Allen always claimed that it was the first one built primarily for passenger travel, the pre-existing ones having been built mainly for the transportation of coal and freight.

Such, in brief, was Mr. Allen's connection with the early railroad enterprises of the United States. He brought to the work valuable initiatives and mechanical inventions and performed an important part in the pioneering of transportation by steam and rail. He early retired from the special field in which he exerted so useful an activity—that is, from railroad engineering, though he continued to carry on his profession for many years and had much to do with railroads as a director and executive officer.

He became connected with the Croton

aqueduct in New York as principal assistant engineer, and had particular charge of the construction, among other things, of High Bridge over the Harlem river in New York city. He was for some time president of the Novelty Works, in the same city; was president of the Erie Railroad Company on its first formation, and in 1872-3 was president of the American Society of Civil Engineers. He lived in semi-retirement for many years and died at his home in South Orange, N. J., on December 31, 1889.

Current Topics.

THAT the contest of the corps of engineers of the United States Navy for military rank and increased numbers, has aroused great bitterness within the naval personnel, is forcibly and unpleasantly shown by the press reports of the charges filed by Captain Philip H. Cooper, superintendent of the United States Naval Academy, against Commodore George W. Melville, the engineer-in-chief of that service. These charges have received, apparently, no consideration whatever from the secretary of the navy, and, in detail, have not been given publicity. It is understood, however, that they are based on statements made by the engineer-in-chief in an article printed in the *North American Review*, in which the words occur:—"Annapolis is either unable or unwilling to train naval engineers, and, if its work is brought into comparison with that of other institutions, the naval academy will be compelled to extend its engineering curriculum or show cause for its existence." As to the official standing of the report of the superintendent, it may be said that the United States navy regulations require officers of all grades to obtain the permission of the secretary before giving their views in print. That this permission was given in this case, does not admit of doubt; and, since the publication of the article was thus authorised, no charges founded upon it would seem to carry weight, especially with so impartial an official as the present secretary of the navy.

MOREOVER, the propriety of the views of the engineer-in-chief is beyond question. The institution at Annapolis had, at one time, a notably thorough engineering course, the students entering by competitive examination. Some of the graduates of those days hold, now, professorships of engineering in the Lawrence Scientific School of Harvard University, and in the Universities of

West Virginia, Cornell, Ann Arbor, Mich., and Pennsylvania. In recent years, however, there has been a change. The special course of four years for cadet engineers has been abolished; all cadets receive the same instruction for three years, and it is only during the fourth, and last, year that professional studies are pursued by the cadets transferred, at that time, to the engineer division. The reason for this change, in a navy which has become wholly engineering, can be only that indicated by a candid officer of the line, who is reported to have said:—"The engineers were getting so many able men, that we had to stop it; otherwise, as they came over one gangway, they would have driven us over the other." It seems to have been a question of the preservation of the prestige of the line branch.

THE Naval Academy does not exist to further the interests of any one corps in the United States Navy. One purpose for which it is maintained by the government, is the training of engineer officers. If this work is not performed properly, the nation may well call its faculty to account, and Commodore Melville will be supported in his statement and honoured that, in making it, he has shown the full courage of his convictions. The position which this officer holds in popular estimation is well stated by the *Globe*, of London, England, which says:—"Outside his profession, of which he is so brilliant an ornament, he gained fame and admiration for the heroic way in which he took charge of the ill-fated Arctic expedition of the *Jeannette*, after the death of her captain and so many others. * * * His countrymen are very proud of him." Of his landing, to plant the flag on Henrietta Island in those northern seas, De Long, the commander of the *Jeannette*, said in his *Journal*:—"Near the island, the ice was all alive, and Melville left his boat and supplies, and, carrying only a day's provisions and his instruments, at the risk of his life went through the terrible mass, actually dragging the dogs, which, from fear, refused to follow their human leaders."

WHEN, later on, that commander and his boat's crew landed in the Lena Delta and wandered on to snowy graves, Melville, practically alone, set out to find them; and, in the record of human endeavour, there is nothing finer than the story of his long search, as he faced the fierce wind and driving snow, half starved, with crippled and bursting limbs, the deadly cold benumbing all else but the iron will and the dauntless courage. Commodore Melville has, further, been one of the builders of the modern fleet of the United States. Many millions of dollars have been expended by his bureau in this, with such success as could have been won only by a man of his forceful genius as a designer, his great administrative ability, and his sterling integrity. The filing of trivial and unwarranted charges against such an officer constitutes an indignity upon him which is unjustifiable. One does not measure mountains with a two-foot rule, and the micrometer of the martinet is not the gauge for men of his mould. Such facts, indeed, have come to light as to "queer doings in the navy" that one may well wonder whether the traditional combination of "officer and gentleman" is not one that should be much qualified when applied to any one of that crowd of undignified land sailors who, for either want of sea service, or chronic distaste for their legitimate profession, can find nothing much better to do at Washington than trying to belittle and harass the naval engineer and injure the efficiency of the service by methods that would do credit to an American ward politician.

THE overwork to which naval engineers are subjected was again evidenced in the eight-day manœuvres, a short time ago, of the North Atlantic

squadron of the United States navy. On the battleship *Indiana* Chief Engineer Tower and one of his assistants, A. McAllister, collapsed. This represents 50 per cent. of her complement of engineer officers. That is to say, the "endurance" of the battleship *Indiana*, under easy manœuvres in time of peace, is practically just eight days, as far as her absurdly insufficient engineering complement is concerned. There seems no doubt that, in the event of war, there would be naval collapse under present circumstances. In addition to the officers mentioned, several machinists and a number of firemen were brought up from below prostrated. Within the past few weeks also Chief Engineer Brothwick, of another ship, was recommended for retirement, by reason of injuries incident to active service. This is a pretty sorry record—one that any naval power, worthy of the name, should be ashamed to have known. The only consolation that the United States has in the matter is the poor one that the British navy is in a similar, but not so hazardous, a plight. One would think that both governments would promptly take sensible measures, tending to a proper valuation of naval engineers' services, and a decent recognition of the fact that they are all-important to the value of their men-of-war as fighting machines.

SPECIALISATION in professional pursuits, in engineering particularly, has become the natural and proper result of the growth of applied science. The civil engineer of past generations, who was supposed to command a comprehensive knowledge of every branch of engineering then practised, from the design of a steam engine or machine tool to that of a bridge, or city drainage system, or complete water works plant, has virtually ceased to exist, and in his stead we find the steam engineer, the sanitary engineer, the bridge engineer, and the engineer of various other subdivisions of the great field of engineering, each an expert in his particular line. It has been found impossible for one man to combine within himself the detail knowledge necessary to practise all these branches with entire success. One branch alone is almost sufficient to make a life study, and the engineering specialist of to-day finds himself busily enough occupied in keeping abreast of the times.

WHAT is true of professional work is quite as true of manufacturing operations, and there is, thus, every reason to believe that the builder who will confine himself to one particular class of, say, machine tools, or steam engines or other machinery, will be able to turn out a better article all around than one who builds a large line of machinery of miscellaneous character. In the one case all the interest of the maker is centred in just one product, all his energies are devoted to making that an example of the highest type of excellence, and all his experience is given to that account. His name and reputation become embodied in the machine. He is not apt to be satisfied with turning out a fairly good machine, but will be more likely to strive toward making the best machine that his brains, and capital, and shop facilities can produce. The large shop, with miscellaneous output, may be divided up into departments, each devoted to one particular manufacture, and each under competent direction, and yet the result will probably not be quite the same. The personal element of pride will be more or less lacking. The machines will be without the stamp of individuality.

APROPOS of these remarks there comes to mind the story told of the maker of the Maydole hammers, whose name, in the United States, has become so well associated with his goods that it is, in itself, a guarantee of the very best quality. In an address before one of the business colleges, a number of years ago, the late President Garfield related it as an illustration of the success that

is sure to follow persistent effort in a worthy cause when exerted in the proper direction. What he said of Mr. Maydole will bear repeating:—"Thirty years ago a boy was struggling through the snows of Chenango Valley, trying to hire himself out to a blacksmith. He succeeded, and learned his trade; but he did more. He took it into his head that he could make a better hammer than any other man had made. He devoted himself to the task for more than a quarter of a century. He studied the chemistry of metals, the strength of materials, the philosophy of form. He studied failures. Each broken hammer taught him a lesson. There was no part of the process that he did not master. He taxed his wit to invent machines to perfect and cheapen his processes. No improvement in working steel or iron escaped his notice. What may not twenty-five years of effort accomplish when concentrated on a single object? He earned success; and now, when his name is stamped on a steel hammer, it is his note, his bond, his integrity, embodied in steel. The spirit of the man is in each hammer, and the work, like the workman, is unrivalled. Mr. Maydole is now acknowledged to have made the best hammer in the world. Even the sons of Thor, across the sea, admit it. While I was there, looking through his shop, with all its admirable arrangements of tools and machinery, there came to him a large order from China. The merchants of the Celestial Kingdom had sent down to the little town to get the best that Anglo-Saxon skill had accomplished in the hammer business. It is no small achievement to do one thing better than any other man in the world has done it." It is told, too, that at one time a visitor to Mr. Maydole's shop, after having gone through the establishment, said to him that evidently he made "a pretty good hammer," to which the response quickly came, "No, I do not make a pretty good hammer. I make the best hammer in the world."

THE Lartigue single-rail system of railways has again put forward a claim for attention in England, Mr. F. B. Behr, of London, at present urging its advantages for high-speed passenger service. For this, however, it will scarcely commend itself to many engineers. The actual examples of Lartigue road which have been in operation

ON THE LISTOWEL AND BALLYBUNION LARTIGUE RAILWAY IN IRELAND.

in Ireland and in France for a dozen or more years past have, in fact, confined themselves to the transportation of inanimate things, and at relatively low speeds, too, so that they are certainly not good illustrations of high-speed capabilities. A fair idea of the structure may be obtained from the accompanying sketch, which represents a view on the Listowel and Ballybunion railway in Ireland. The main rail of the road is to be on an elevated structure on which the carriage rests. Extending over a triangular frame, the sides of the car overhang this structure, thus lowering the centre of gravity of the train and obviously increasing stability. On each side of the frame are placed two guide rails for small wheels, which run horizontally and serve to take up the lateral stress. The trouble with these will be mainly at curves where considerable grinding will be inevitable. With

increased stability, the inventor seems to argue, an increase of speed over the present systems of propulsion is an easy matter,—in fact, a possible speed of 150 miles an hour is claimed. Leaving aside all such drawbacks as curves, grinding of the guide wheels on the bottom of the frame, the slipping of the wheels alone would prevent such speeds. On present steam roads increase of speed is, or has been, made possible, by a constant increase of the diameter of the wheels, until we have reached seven-foot drivers. It is not known how large Mr. Behr's guide wheels are, but assuming them to be as much as one foot in diameter, it would require 4177 revolutions per minute, or 70 revolutions per second, to propel the car at a rate of 150 miles an hour. This is, to put it mildly, absurd. The London *Electrical Review* looks upon this system rather doubtfully, but one argument brought is worth noting, for as much as we may agree on other points, this one is certainly open to question. The *Review* doubts that a fast road of this sort, assuming it to be successful, could "create a hidden and undeveloped mine of traffic which is to spring into being with the facilities he offers." We know from experience, however, that this very thing has often occurred. There are roads in a great many places which have been a financial success from the first day of their existence, and from this point of view Mr. Behr may gather some hope.

At this time of writing, Messrs. Thornycroft & Co., the well-known English builders of torpedo boats, are going through a unique experience in the way of a strike. The trouble is about the construction of water tube boilers, the introduction of which has changed the boiler work for vessels, where they are to be used, from a riveting together of great shell structures, to the attachment of a series of pipes by means of screw joints. The manufacturers who made contracts with the Admiralty to build these boilers thought the fitters, or engineering artisans, were best suited to do the work and turned it over accordingly to them. The fitters belong to the powerful English trades union known as the Amalgamated Society of Engineers. While the innovation was in the experimental stage the boiler makers made no trouble, but when it became apparent that the new form of construction was likely to revolutionise the whole boiler industry, the strong Boiler Makers' and Iron Shipbuilders' Society stepped in and demanded that the work should be done only by members of their union. This point of difference between the two great unions was one of the difficulties to be settled in the recent strike that closed the Irish and Scotch shipyards. An arbitrator there decided that the work should go to the boiler makers.

The Thornycrofts, as is well known, have made a specialty of the delicate machines known as torpedo boat destroyers. When the boiler makers came to them, insisting that the boiler work should be turned over to members of their union, the firm proved conclusively that more skilled mechanics were needed than the union could supply, but finally agreed to stop work on such boilers till the two unions could come to some agreement as to what should be done. So long as they could fulfill their contracts they were willing to leave the decision of this matter to the men. The result has been that for three months work has been stopped, penalties for the delay are accruing on government contracts and those with foreign purchasers, while the strike is no nearer settlement than it was at the beginning. On some boilers which were completed and only need to be tested the firm asked the men to allow the testing to be done by outsiders, without prejudice to the question pending, and the men refused. The latest development is that all the fitters at the Thornycroft works have gone on strike, and the firm have informed the boiler makers that in consequence there will soon be no work for them to do. The folly

and selfishness of this strike cannot be concealed. There is plenty of work for all the men, so soon as they agree to a new adjustment, in answer to an inevitable change of conditions, sharing the work between them equitably. The strike is doing serious injury to the labour cause, as public sympathy is naturally with the innocent employers, who are suffering on account of the obstinate fight for monopoly in work by the unions to which their workmen belong.

With smoke preventing devices galore, a timely interest is attached to the recent well-put exposition of the requirements which such an apparatus should fill. It was made by Professor C. H. Benjamin before the Civil Engineers' club, of Cleveland, as part of a discussion of the ever-present problem of fuel economy and smoke suppression. In the first place, according to Professor Benjamin, there should be the possibility of varying the feed of the stoker quickly and conveniently. In the second place, it is necessary that the spacing of the grate bars should be variable; that the air spaces between the bars may be varied, and the coarseness and fineness of the grate may be quickly adapted to the particular kind of coal used. Third, it is necessary that the grate bars should be of the automatic shaking type, so as to prevent the formation of clinkers and facilitate the dropping of the ashes. Some form of air control is quite important. Almost any form of stoker or grate under hard service needs a high chimney. The great difficulty in many establishments is that the chimney is not high enough and the draught not powerful enough. There should be a margin, and the fireman should have the means of controlling it. If there is not enough draught, the fireman cannot do anything; if there is too much he can easily reduce it. It is impossible to get good results with a small grate. A grate which is large enough under ordinary conditions is not large enough under sudden emergencies.

In order that a stoker may commend itself to a purchaser, it should be easily accessible for cleaning and repairing, and it should be so located that it can be taken out and replaced without tearing out the whole front of the boiler. This is one of the serious objections to several forms of stokers which otherwise are very desirable. Where the feed water is pure, the water grate is a success, but with scale-forming water it will give more or less trouble. Among the requirements in smoke prevention no item is of such importance as good firing. A good fireman can, with an ordinary grate, give good economy, and, to a large extent, prevent the formation of the smoke, if the boiler is not forced beyond its capacity. A good fireman is just as necessary with any form of stoker that has ever been used. The reason why so many chimneys smoke is partly because there is not enough fireman and also because there is not enough boiler. A judicious selection of stoking apparatus, a chimney of proper size, a boiler which is at least half as big as it ought to be, and a fireman who is worth more than a common labourer's wages,—these, Professor Benjamin sums up, are the principal things necessary to prevent smoke.

In connection with Professor Benjamin's specifications in this matter a recent editorial in *The Engineer*, of London, is worth noting. Speaking of the attempt which was made in Sheffield a short time ago to reform the condition of the atmosphere by abating the almost intolerable smoke nuisance, and from which, by the way, nothing has come in the way of improvement, *The Engineer* says:—"The smokeless furnace is not in all cases and ways desirable. Much nonsense has been said and written about the waste of fuel entailed by the production of smoke. It has been pointed out, however, that as a matter of fact the quantity of carbon thus wasted is quite insignificant. A few ounces of coal will leave a trail in the air half a mile long. Baffled on this

score, the smokeless folk have persistently urged that the waste was not due to unburned carbon, but to the production of carbonic oxide, instead of carbonic acid, in the furnace. But careful experiments, conducted under all sorts of circumstances, have shown that this evolution of carbonic oxide is a myth. Beyond this, Dr. Anderson has directed attention to the fact that a non-luminous gas flame has little or no radiant heat, and that for the purpose of making steam, a smoking lurid flame may be, and usually is, far superior to a bright fire and a clear flame. Moreover, the prevention of smoke is commonly effected by the admission of a large volume of air over the fire—much more air than is needed for combustion. The result is that it is no uncommon thing to find a boiler which has steamed well while the chimney gave out volumes of smoke, steam very badly indeed when fitted with smoke preventing appliances. Many years ago a determined effort was made to prevent certain tug boats on the Thames from smoking. The attempt was in one way quite successful; in another it was a total failure, because the boilers could not make steam enough under the new conditions. Facts such as these are not easily realised. Many worthy persons are slow to believe them, or will not believe them at all. But they go very far to explain the apparent apathy of steam users, and their reluctance to interfere with firing arrangements which have served them well.

"AGAIN, nothing is more often heard in this connection than the statement that the prevention of smoke means a direct reduction in coal bills. The statement has no general application. It is true of certain special cases, but not of all. If there is really one-half the money to be made that the world is told may be made by preventing smoke, then no smoke would be seen. As a rule, it will be found probably a little more expensive to prevent smoke than not. In particular cases automatic stokers have effected a considerable saving; but this, as a rule, has had nothing to do with smoke prevention. The firing machine permits an inferior fuel to be burned, and there is a saving in consequence. Small slack at 3s. 6d. a ton takes the place of round coal at 8s. 6d. There is here a large margin for economy. We do not wish it to be assumed that we are opposed to the prevention of smoke when coal is burned to make steam; far from it. But we assert that the thing should be done, not because money is to be saved thereby, but because it is expedient that the atmosphere of our towns and cities shall be kept as clean as possible. Smoke, in one word, should be prevented, not in the hope of reward, but simply because it is right."

A GOOD illustration of the growing appreciation of electric storage batteries for central station work is afforded at Zurich, in Switzerland, where the station which supplies current for lighting the city, has put them to use in helping to manage the night load. The latter has for some time been near the maximum output of the station, and the street mains, too, were not adequate for dealing with much heavier currents than those employed at the time. When the demand came for current for lighting the new large music hall of the city, it was, therefore, decided to install an accumulator plant in the cellar of the building and to charge the batteries from the central station during the day time when the load, up to that time, had been relatively light, thus tending to level the load line,—that ever present problem for the station manager,—and at the same time avoiding the making of any changes in the service mains. The consumption of current for the music hall is equivalent to two thousand 16-candle power lamps. The station current is alternating and current rectifiers are, therefore, used to change it to continuous current for charging the batteries.

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